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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 98. - 102, 1911-12

L. O. HOWARD, Entomologist and Chief of Bureau.

HISTORICAL NOTES ON THE CAUSES OF BEE DISEASES.

BY

E. F. PHILLIPS, PH. D.,

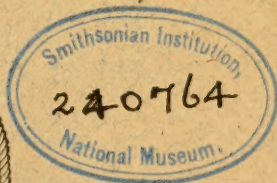
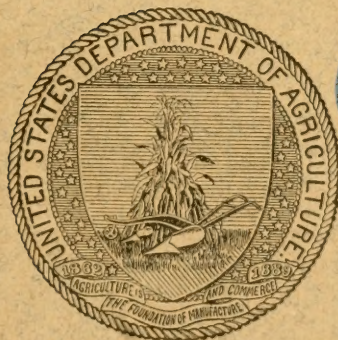
In Charge of Bee Culture,

AND

G. F. WHITE, PH. D., M. D.,

Expert in Bacteriology.

ISSUED MARCH 26, 1912.



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WASHINGTON:
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BUREAU OF ENTOMOLOGY.

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H. A. SURFACE, D. B. CASTEEL, *collaborators.*

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 27, 1911.

SIR: I have the honor to transmit herewith a manuscript entitled "Historical Notes on the Causes of Bee Diseases," prepared by Drs. E. F. Phillips and G. F. White, of this bureau. The investigations of the causes of bee diseases are highly important in the control of these maladies. Many of the papers on this subject are not available and many also record errors in observations and conclusions. The purpose of the present paper is to assist bee keepers in obtaining a proper understanding of the work done by the various investigators whose papers are discussed. I respectfully recommend the publication of this manuscript as Bulletin No. 98 of this bureau.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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PREFACE.

Bees, like many other members of the animal kingdom, are known to suffer from diseases. Simultaneously with the good work that has been done during the last half century toward the determination of the causes of the various diseases of man and animals, there has been some work done on the causes of bee diseases. This work has caused considerable literature to be written on the subject. Although this literature contains much that is valuable, it abounds in statements that are erroneous and in conclusions that seem unjustifiable. Many of the inaccurate statements and conclusions have been frequently copied in the past and they are still too often copied into the current literature on bee diseases. The bee keeper, therefore, in reading is often at a loss to know what is true and what is untrue; what is actually known and what is not known.

For the purpose of aiding the bee keepers with this literature, we have reviewed here portions of several original papers dealing with the causes of bee diseases. It is hoped that this bulletin may serve as a means whereby the bee keeper may solve for himself some of the apparent mysteries found in beekeeping literature.

In selecting the papers for review, for the most part, those were chosen which were written by men who had worked more or less on the causes of bee diseases. The reviews that have been made contain the more important beliefs concerning the causes of these diseases that were entertained by the authors of the different papers at the time they wrote. The classification of the diseases of bees as understood by these different men is also frequently included. The original papers naturally contain much that has not been mentioned in these brief reviews, and therefore the reader is urged, if opportunity permits, to read the papers cited in this bulletin rather than the reviews. It is probable that the papers here considered might with profit have been more completely reviewed and that other papers might with profit have been considered, but if either had been done it is probable that the length of the bulletin would have defeated its object.

It is hoped that the readers of bee-disease literature will learn, so far as possible, to judge correctly an article that discusses in any way the causes of bee diseases. To do this, one should first of all learn who are actually doing work on the causes of these diseases.

The writings of all these men should be read. If an investigator has done work on the causes of other diseases than bee diseases, but chooses to write on bee diseases, the reader will usually profit by reading his papers. The great mass of literature, on the other hand, created by those who have not worked on the cause of any disease can as a rule with profit be rejected.

Having determined whose papers should be read, the character of the work of each investigator should be carefully noted. If the character of a man's work proves to be good, give weight to all his statements, but if the character of a man's work is poor, expect untrue statements and erroneous conclusions. If one will learn in this way to judge the different papers, one will soon know what to believe and what to suspect, but if one does not learn to do this he will be forever at the mercy of printed pages.

As the reader forms his opinion of the character of the work done by the different men referred to in this bulletin, permit the suggestion that he exercise some leniency inasmuch as the time at which a man works and the circumstances under which he labors are frequently in a measure responsible for mistakes. The reader will note, however, that many times the mistakes made in the study of bee diseases have been made only because insufficient and careless work was done by the investigator. In such cases no leniency is to be exercised in arriving at conclusions.

The writers of this bulletin have commented very little on the character of the work done by the different authors of the papers reviewed. The views of these men as they are found in the papers are given and the reader is allowed and urged to judge for himself whether or not such views are true. To aid the reader, however, the writers have made a few suggestions when it was thought that they might prove advantageous. The page references refer to pages in this bulletin.

In reading a paper there is always the danger of misinterpreting an author's conception. This danger is greatly increased if the author of the paper criticized uses a foreign language. Realizing this possible source of error, we have endeavored in every case to be cautious. When quotations from papers written in a foreign language were selected, rather free translations of them into English have been made.

We disagree with a very large number of the statements which have been made by different authors referred to in this bulletin concerning the causes of bee diseases. Therefore let it be emphasized that the reviews which are here made are intended to express the opinion of the author of the paper reviewed, and not by any means the opinion of the writers of this bulletin.

To entomologists who feel an interest in the causes of insect diseases and who wish to be able to judge with some satisfaction the work that has been and is being done on insect diseases this bulletin will be of special interest. It is believed that by the learning of the mistakes made by workers on bee diseases, and by the learning of the causes for such mistakes, the careful reader will be enabled to judge more accurately the value of the various reports that appear on the diseases of insects.

THE AUTHORS.

HISTORICAL NOTES ON THE CAUSES OF BEE DISEASES.

INTRODUCTION.

Bee keepers, as a rule, manifest a keen desire to know about the causes of bee diseases and they show a lively interest in the investigations leading to the determination of the causes. This is gratifying to those working on these diseases and will be a great benefit to the apiarist who must treat the diseases. The losses to apiculture from diseases are enormous, and inasmuch as the successful treatment of a disease depends largely upon a knowledge of the cause of the disease to be treated it behooves every owner of an apiary to become as familiar as possible with the causes of bee diseases.

The facts that are known about the causes of bee diseases unfortunately are altogether too few. As this can be said of all diseases affecting the animal kingdom, the bee keeper has no cause for despair. An attempt, however, will be made in this bulletin to furnish data from which the bee keeper may be able to inform himself concerning the facts that are really known about the causes of bee diseases.

In this introduction it might be well to classify the bee diseases as the writers of this bulletin understand them. Bee diseases can be conveniently classified under those affecting the brood and those affecting the adult bee. The most important brood diseases are American foul brood, European foul brood, and the so-called "pickled brood." The disorders affecting adult bees that are of most importance are being referred to at present under the names of paralysis, dysentery, and Isle of Wight disease.

American foul brood.—American foul brood is a very widely distributed disease and better known to bee keepers than European foul brood. It is the one which is generally referred to by the bee keeper at the present time when he speaks of "foul brood." The brood affected with this disease is usually capped before it dies. The color of the dead brood presents in general various shades of brown. The marked ropiness of the decaying remains of the dead larvæ is probably the most characteristic and well-known feature of the disease. The punctured cappings, the scales formed from dried-down larvæ, and the disagreeable odor sometimes present are aids to its diagnosis. This disease is clearly an infectious one. The exciting cause of it is a bacterium known as *Bacillus larvæ*.

European foul brood.—European foul brood is the disease which Cheshire and Cheyne (p. 25) described in their studies of foul brood. Howard (p. 44), of Texas, made a very brief and unsatisfactory study of this disease at one time and named it "New York bee disease" or "black brood." We are strongly inclined to believe that Burri (p. 68) was working with this disease for the most part during his study of the condition which he refers to as "sour brood." European foul brood is less widely distributed in this country than is American foul brood. In European foul brood one finds, as a rule, most of the diseased brood as yet uncapped. In general, the brood dead of this disease presents various shades of yellow. Usually there is no ropiness; at times, however, there is. That degree of ropiness, however, which is so characteristic of American foul brood is seldom present in European foul brood. There is frequently a slightly sour odor to the diseased brood. The rapidity with which this disease spreads in a new territory and the marked destructiveness of it are features which most bee keepers have experienced who have been so unfortunate as to have the malady affect their apiary. The disease is clearly, therefore, an infectious one. The exciting cause is not known. Claims are made by some that certain species of bacteria stand in direct etiological relation to the disease, but satisfactory evidence to prove such contentions are wanting.

The so-called "pickled brood."—Howard (p. 42), of Texas, described what he chose to call pickled brood. His findings have never been confirmed. The name "pickled brood," however, is very frequently used by bee keepers in referring to a diseased condition of the brood. Howard's description of "pickled brood" (p. 43), however, does not apply to such a condition. Since the name "pickled brood" is not accurately applied and is, moreover, entirely inappropriate for the condition which we find, we prefer for the present to use the expression "so-called pickled brood." In this condition the brood dies about the time of capping. The body wall of the larva, in a case which might be called typical, is intact and rather tough. When this wall is broken, one often finds a watery content in which is suspended a granular substance. As a rule a very small proportion of the brood is affected. The disease does not seem to be infectious. The loss to the colony in comparison with European foul brood and American foul brood is slight. This disorder, therefore, should arouse no great amount of fear. While the number of colonies lost from this disease is comparatively small, in the aggregate many bees die as a result of the condition. The disease has a very wide distribution. The exciting cause is not known.

There is very little that is definitely known about the diseases of adult bees. They have not been sufficiently investigated to make it possible to classify them with any degree of satisfaction.

Paralysis.—But little is definitely known about paralysis of bees. The disease has not been demonstrated to be infectious. Many suppositions have been made by different writers as to the cause of the trouble, but no satisfactory evidence has been produced to prove the cause.

Dysentery.—A condition known as dysentery has often been observed by the bee keeper. But little is known about the disorder. There is considerable evidence that the nature of the winter food plays a part in its causation. Zander (p. 89) has recently suggested that there are two forms of this affection, a noninfectious one and an infectious one. To an infectious form he ascribes *Nosema apis* as a cause. Much work must yet be done upon this condition.

Isle of Wight disease.—The disorder known as Isle of Wight disease was first reported from the Isle of Wight by Imms (p. 79). Malden (p. 93) reports that the disease has more recently spread to the mainland (England). This disorder has so far not been found in any other country. The cause has not been definitely established.

It is urged that the reader peruse the preface to this bulletin (pp. 7-9) carefully. By so doing the intent of the writers of this bulletin will be better understood and the chances of misinterpretation will be lessened.

CONSIDERATION OF PAPERS ON THE CAUSES OF BEE DISEASES.

SCHIRACH, 1771.

Schirach¹ in 1771 classified the diseases which most frequently attack bees as follows: (1) Dysentery; (2) disease of the antennæ; (3) foul brood; (4) queens laying drone eggs only; (5) sterile queen; (6) queenless colonies.

Dysentery he considered to be dietary in origin. No belief is expressed as to the cause of the disease of the antennæ, to which he refers, but he states that with this disease the danger is not great. The disease which he designates as foul brood, however, he believed to be quite dangerous, very fatal, and a true pest after it has reached a certain stage. To this condition he attributed two causes, one cause being ascribed to the improper food which was consumed by the larvæ, and the other being a fault of the queen in permitting the brood to be so arranged in the cells that the heads point inward. Considering these two widely different causes ascribed to an abnormality in the brood, one might suspect that there was more than one disease in the condition which he designated as foul brood. That part of the disease condition, to which as a cause he ascribed the food, could well be an infectious disease—either American foul

¹ Schirach, A. G., 1771. *Histoire naturelle de la reine des abeilles, avec l'art de former des essaims.* La Haye. Pp. LXIII+269; 3 plates.

brood or European foul brood. The other form of the disease, in which the brood was supposed to be placed with the head directed inward, most probably was not an infectious disease. In the treatment of foul brood Schirach recommends the removal of all combs from the bees. This principle is the one upon which is based the methods which are most successful at the present time in the treatment of the infectious brood diseases.

The other abnormalities in the colony which are mentioned in the paper relate to the condition of the queen. These are conditions familiar to the bee keeper, but which may occur more often when an infectious brood disease is present. Mention is also made of the fact that brood is sometimes killed by chilling. Schirach refers to this as an accident and not as a disease.

LEUCKART, NOVEMBER 12, 1860.

Leuckart¹ had entertained the opinion that infectious foul brood was due to a fungus, and he felt that his view was strengthened by some work which was done on the diseases of the silkworm. During the summer of 1860, however, he had an opportunity to see much infectious foul brood in samples of comb and in colonies. In the diseased material he found no fungi that he could not attribute to the phenomenon of decay. He states in the paper that foul brood is obviously a collective name that includes various forms of disease with the features in common of being epidemic, attacking early stages, and being usually fatal. One sample was examined, and a number of diseased and dead larvæ was found to contain an unidentified fungus. The majority of them, however, did not contain the fungus; yet these latter larvæ were thought to be dying of the usual type of foul brood. From his summers' experiences Leuckart arrived at the conclusion that the infectious foul brood was not due to a fungus.

MOLITOR-MÜHLFELD, APRIL 15, 1868.

Molitor-Mühlfeld² in 1868 reported some startling observations relative to the cause of foul brood. He writes that foul brood is of two kinds, the mild kind and the so-called infectious or virulent one. The mild form of foul brood, according to his views, resulted from a chilling of the brood. During the early warm days of spring, he argues, brood rearing is stimulated to such an extent that when colder weather follows it is impossible for the bees to care for all the brood, and as a result the neglected brood is chilled, dies, and be-

¹ Leuckart, Dr., November 12, 1860. *Zur Naturgeschichte der Bienen*. 3. *Zur Kenntniss der Faulbrut und der Pilzkrankheiten bei den Bienen*. Eichstädt Bienenzeitung, 16 Jahrg., Nro. 20, pp. 232-233.

² Molitor-Mühlfeld, April 15, 1868. *Die Faulbrut, ihre Entstehung, Fortpflanzung und Heilung*. Eichstädt Bienenzeitung, 24 Jahrg., Nro. 8, pp. 93-97.

comes foul. From this condition, this author stated, no danger is to be feared, as the bees afterward remove all this dead brood, leaving the colony free from danger. The cause of the virulent form of foul brood is attributed by Molitor-Mühlfeld to a small parasitic ichneumon fly, reddish-yellow in color and scarcely one-sixth of an inch long, to which he gave the name *Ichneumon apium mellificarium*. He writes that this fly had already been observed about foul-brood colonies by another writer, but that it was thought to be a carrion fly. Concerning the life history of these flies, he says that they press into the hives and lay their eggs in the bee larvæ. The larvæ live in spite of this until the cell is capped and the cocoon is spun. During this time the fly larvæ feed upon the fat of the bee larvæ, and finally bore their way out of the body into the cell, undergo metamorphosis, and in a few days escape from the cells through openings which they make in the center of the cell-capping. These young adult flies now mate, sting other bee larvæ, lay their eggs, and continue the cycle. The time which elapses from the egg of this parasitic insect to the adult is given as about from 10 to 12 days. This, to his mind, explained the rapid increase of the exciting cause of foul brood. As a result of the parasitic existence of this fly in the bee larvæ, these larvæ die and change into a ropy, sticky, ill-smelling mass which the bees can not remove.

Furthermore, he argues that if instead of the diseased larvæ dying, as they do, after capping, they should die before this stage was reached, then the dead bodies would be removed early and with them the larvæ of the fly; but since the brood is always capped before death takes place the capped cells afford a protection for the parasitic insect until it becomes an adult ready to emerge.

In making a diagnosis, it is stated, the cell-cappings should be examined, and if they are punctured then the disease is positively the infectious foul brood. As a treatment for the infestation of the brood by this insect in a colony in which infectious foul brood already exists, it is recommended that the combs be removed to a clean hive with new foundation, and that the treated colonies and other colonies in the apiary be protected by pouring at frequent intervals camphor dissolved in oil of turpentine, between the hives in the yard and also sometimes on the alighting boards. This is done to prevent, by the odor of the turpentine and the camphor, the entrance of the ichneumon fly into the hives.

PREUSS, OCTOBER 1, 1868.

In a paper written by Preuss,¹ in 1868, his views on the causes of foul brood are given. The distinction which he would make between

¹ Preuss, Dr., October 1, 1868. Das Wesen der böartigen Faulbrut besteht in einem mikroskopischen Pilze, *Cryptococcus alvearis*. Sie kann verhütet und geheilt werden. Eichstädt Bienenzeitung, 24 Jahrg., Nro. 19 u. 20, pp. 225-228.

mild and virulent foul brood is, that virulent foul brood is caused by a fungus which he named *Cryptococcus alvearis*, and that the mild foul brood is due to some other cause. His conclusion concerning the virulent foul brood was reached through a microscopic study of foul-brood material. Preuss had been somewhat familiar with bee-keeping since early boyhood, and had had the opportunity of visiting numerous apiaries in the Vistula Valley, but had not encountered foul brood until in 1866, when a friend had called his attention to the disease in an apiary of the latter in which he was using the Dzierzon hives. Preuss immediately undertook the investigation of the character of the disease by studying microscopically the larvæ which had died of the disease. A small bit of the dead larvæ was added to a little water, covered with a glass, and studied in the fresh condition. Numerous spherical bodies measuring $2\ \mu$ in diameter were seen and identified by him as belonging to the genus *Cryptococcus*, to which he gave the name *Cryptococcus alvearis*. Larger objects which were present were recognized as fat bodies.

Very nearly related to this organism, Preuss writes, is a fungus that causes fermentation, *Cryptococcus fermentum*. It was his belief that if this latter species infected or fell upon a larva it might, under favorable temperature and moisture conditions, change into *Cryptococcus alvearis* and in this way produce foul brood. Practical bee keepers had, prior to this time, emphasized the danger of foul brood transmission by the feeding of fermented honey. One bee keeper of large experience had attributed foul brood to meal feeding, and since meal is a good medium for the growth of fungi, Preuss was inclined to favor the view. He argued that since the fungus of fermentation is widespread in nature, the brood dying from cold or neglect of any kind may constitute a fruitful soil in which this fungus could grow and thus become the cause of infectious foul brood. Medication in the treatment of the disease Preuss held to be quackery and recommends instead the removal of the diseased frames from the hive, but not the destruction of the hives. The hives were to be washed with 10 per cent sulphuric acid, followed by water, and afterwards put into an oven and heated to the boiling temperature for some hours. The frames containing diseased material were to be burned, and those frames which were free from such material were to be used again. All dead bees were to be buried, as they might become a source of fungous growth, and the ground in front of the hive was to be sprinkled with sulphuric acid and then dug up deeply.

SCHÖNFELD, NOVEMBER 15, 1873.

In the absence of conclusive experimental proof, the theories advanced by Preuss in the paper just considered were not univer-

sally accepted. Schönfeld,¹ therefore, set about to supply incontrovertible evidence to prove the cause of infectious foul brood. He received a small mass of decaying larvæ about the size of a pea and placed it under an inverted funnellike apparatus. An opening for the admission of air was made from below; the exit was an opening above in which was placed a stopper made of cotton. Placing this apparatus near the window, that it might receive the heat of the sun, he hoped, by the current of air which would thus be produced, to collect on the cotton, filling the exit, the spores of the fungus which would be floating off in the air from the foul-brood mass. Upon examining the cotton he found what he supposed was the fungus in the form of a micrococcus. This was the first part of his experiment. In the second part of it he used this cotton to infect healthy larvæ. Four square inches of brood was covered by a layer of cotton. The cotton was taken from one of the stoppers that had been contaminated with the fungus by means of the apparatus. After two unsuccessful trials he made a third attempt, which was considered by him as being successful. After a lapse of four days seven larvæ had died and numerous micrococci were found in their dead bodies.

In another experiment the same author used the larvæ of the blow-fly (*Musca*), *Calliphora vomitoria*. Some cotton contaminated in the manner outlined in his first experiment was placed upon some meat upon which these larvæ were feeding. Nine days after adding his supposed virus he found dead larvæ which upon microscopic examination revealed to him again the presence of numerous micrococci. The results of these experiments convinced him that this micrococcus was the cause of infectious foul brood, and he believed that the fact would be accepted without question.

The experiments of Schönfeld were not, however, universally accepted as conclusive. This induced him to perform other infection experiments. This time he used caterpillars of (*Pieris*) *Pontia brassicæ* and (*Pieris*) *Pontia rapæ*. The virus was mixed in distilled water and painted on the exterior of the insect, with the result that those so treated died while the checks developed normally to healthy pupæ. Microscopically, however, the check caterpillars showed also the presence of the fungus. This caused him to doubt somewhat his conclusions relative to the blowfly experiment. He believed, however, that sufficient evidence had now been produced to justify the conclusion that infectious foul brood is a mycosis and that the fungus *Cryptococcus alvaris* is the exciting cause of the disease.

¹ Schönfeld, Dr., November 15, 1873. Faulbrut-studien, Pt. I. Eichstädt Bienenzeitung, 29 Jahrg., Nro. 21, pp. 250-254; January 15, 1874. Faulbrut-studien, Pt. II, Eichstädt Bienenzeitung, 30 Jahrg., Nro. 1, pp. 3-5.

DZIERZON, 1882.

For many years Dzierzon and others entertained the belief that there existed two forms of foul brood, a mild form and a virulent one. In his "Rational Bee Keeping," Dzierzon¹ has written the following concerning the kinds of foul brood.

There is one kind that is mild and curable, and another kind malignant and incurable; both kinds are, however, contagious.

The curable occurs in this way: More of the larvæ die still unsealed, while they are still curled up at the bottom of the cell, rotting and drying up to a grey crust, that may be removed with tolerable ease. The brood which does not die before sealing mostly attains to perfection, and it is only exceptionally that individual foul-brood cells are met with sealed.

This is exactly reversed in the malignant kind of foul brood. In this the larvæ do not generally die before they have raised themselves from the bottom of the cell, have been sealed and begun to change into nymphs. The rotten matter is, therefore, not found on the cell floor, but on the lower cell wall; it is brownish and tough, and dries up to a firm black crust, both in consequence of the heat prevailing in the hive, and of a small opening bitten in the depressed cover. This matter the bees are not able to remove; and when they are in some strength, they can at most get rid of it by entirely biting down the tainted cells and making fresh ones.

The description which Dzierzon here gives of the "mild" form of foul brood applies very well to European foul brood, and his description of the "malignant" form applies equally well to American foul brood. It is fair to suppose that he encountered both European foul brood and American foul brood, but instead of recognizing them as two distinct diseases, he thought them to be two forms of the same disease.

CHESHIRE, AUGUST 1, 1884.

The work of Cheshire on the cause of bee diseases is of much interest and should be somewhat carefully considered, inasmuch as it has directly and indirectly caused much confusion in the minds of bee keepers concerning the nature, cause, and treatment of foul brood.

The first paper² by him to be considered was the outgrowth of an invitation by a committee of the British Bee Keepers' Association about the last of May, 1884, to give an address before the association on foul brood. A paper of considerable length was prepared and was read before that body of bee keepers on July 25, 1884. In this address the subject of foul brood was taken up under three separate headings: (1) "The nature of foul brood as a germ disease;" (2) "The means of the propagation of the disease;" (3) "The method of

¹ Dzierzon, Johannes, 1882. Dzierzon's Rational Bee Keeping; or the theory and practice of Dr. Dzierzon. Translated from the latest German edition by H. Dieck and S. Stutterd. Edited and revised by Charles Nash Abbott, London. Pp. xvi+350.

² Cheshire, Frank R., August 1, 1884. Foul brood (not *Micrococcus*, but *Bacillus*), the means of its propagation and the method of its cure. British Bee Journal, Vol. XII, No. 151, pp. 256-263.

cure." As Dzierzon and others had done, Cheshire refers to two forms of foul brood. Concerning the appearance of these two forms of the disease, he writes as follows:

The appearance of foul brood is undoubtedly familiar to almost all before me. A larva, if attacked early, begins to move unnaturally, and instead of lying curled round on the base of the cell frequently turns in such a way as to present its dorsal (back) surface to the eye of the observer. A little attention will then show that the colour of the larva is inclined to yellow instead of being pearly white. Such grubs are only rarely sealed over. Those more advanced before the disease strikes them are in due course sealed, but death overtakes them, their bodies become brown and fetid, and the sealing sinking gets pierced by an irregular hole. From this may be gathered the general indications of the disease, which is usually accompanied by very energetic fanning at the hive mouth, from which in advanced cases an indescribable and nauseating odour is emitted. The larvæ and chrysalids dead of the disease dry up to a coffee-coloured, tenacious mass lying at the bottom of the cell, so tenacious, indeed, that it may be drawn out into long threads like half-dry glue. The drying process completed, a blackish scale is all that remains.

Cheshire gives here a description of the disease very similar to the one found in Dzierzon's writings. His description of the disease when it attacks the larvæ early in the developmental stage fits quite well that of European foul brood; and the description which is made of the brood which is attacked later in the stage of development is equally accurate for American foul brood. There is little room for doubt that the two forms of foul brood described by Dzierzon and Cheshire are the two distinct diseases, European foul brood and American foul brood.

Cheshire began his study of the disease by examining the juices of healthy larvæ microscopically. In these he found no bacteria. He then examined the coffee-colored, foul-broody, dead larval mass and observed numerous ovoid bodies which he demonstrated later to be the spores of bacteria. This led him to suspect that Schönfeld had fallen into the error of supposing that these spores were micrococci. Having found numerous spores in the remains of larvæ which had been dead for a long time, he examined some larvæ which were dead but in a fresher condition. In these he observed many rodlike bacteria and fewer spores. He next examined larvæ which showed signs of disease, but which were yet alive, and found their juices to be filled with actively motile rods. These rods were sometimes arranged in chains—leptothrix forms. He now examined larvæ representing the different stages of the disease, and observed: First, that in the beginning of the attack, rods only were seen; second, as the disease advanced, the rods began to form spores; third, as the larvæ assumed the viscid state, spores were very rapidly formed; and fourth, in a few days only spores in very large numbers were found. These observations on the morphology of the bacillus are good, but the conclusion which he drew from them, "Foul brood, then, is a bacillus disease," is of course unwarranted.

Cheshire, believing that foul brood was due to a bacillus and not to a micrococcus, as claimed by Schönfeld, sought to demonstrate the fact by repeating the inoculation experiments of the latter, using the larvæ of the blowfly used by Schönfeld (*Musca*) *Calliphora vomitoria*. Sixty blowfly larvæ were divided into three equal groups: 20 were not brought near foul-brood material; 20 were inoculated with the bacillus in the vegetative form; and 20 with the spores of the bacillus contained in the coffee-colored foul-brood material. Microscopic examination at the end of 24 and 48 hours failed to give evidence of disease in the fly larvæ. After 72 hours, however, active bacilli were observed. Cheshire writes, "This is most completely confirmatory of my position; but how could it be reconciled with Schönfeld's assertion, that he found the dead flies full of micrococci? Had he searched further, he would have discovered that dead blowflies are generally full of micrococci." In demonstrating this error of Schönfeld, he unfortunately made an error quite as great himself.

Cheshire attempted to obtain, by cultures, proof to support his contentions concerning the etiology of foul brood. He prepared a medium by taking drone larvæ and expressing and straining their juices into two test tubes. Tube No. 1 was inoculated with a small quantity of coffee-colored material, which for the most part contained only spores; tube No. 2 was inoculated with a trace of fluid from a diseased larva which contained the vegetative form of the bacillus. These tubes were then suspended in a hive between the frames in order that the temperature for growth might be right. After a period of 22 hours an examination was made. Observing practically no spores and many bacilli in tube No. 1, and many bacilli in tube No. 2, he reached the conclusion that many of the spores introduced into No. 1 had germinated, and that the bacilli introduced into No. 2 had increased by multiplication. From this he concludes that the rods were produced from the spores when suitable conditions permitted the germination of the latter, and that the rods produced the spores when the reverse conditions were present. From the technique used, of course, the data he obtained could be of very little value. Thus Cheshire's culture experiments failed as completely in demonstrating the etiology of foul brood, as did his experiment with blowfly larvæ. The experiment, however, is of some interest as it is among the first cultural work done on bee diseases, and also because here larvæ of bees were used as a medium.

Aside from the larvæ, Cheshire suspected that adult bees suffered from foul brood. He was of the opinion that if two colonies, a healthy and a diseased one are selected for observation, and 5,000 larvæ be removed from the healthy one, and 1,000 larvæ die of disease in the diseased one, that the healthy colony will progress pretty much as though it had lost nothing, while the diseased one will, as a rule,

diminish very perceptibly in strength. This difference in the strength of two such colonies suggested to Cheshire the probability that the adult bees died from foul brood.

In an attempt to settle this question he went to a foul-brood colony and observed one bee dead, another hopping in abortive flight, and finally a third and fourth worn out. The microscopic examination of the first bee was negative, but the second bee was full of active bacilli. This, he believed, was sufficient to answer the question. From this he concluded that workers and drones suffer from the disease, which suggested to him the possibility that the queen suffers also and, if the queens suffer, he says, why are the eggs not also affected? As a result of these observations he suggested that the name foul brood is inappropriate, since as he supposed, the disease affects adults as well as brood.

At this point in his paper Cheshire gave to the bacillus which he saw the name *Bacillus alvei*, meaning bacillus of the hive. This name he claims represents both generically and specifically what the disease really is.

In the treatment to combat the disease he recommended the feeding of phenolated sirup, in the proportion of 1 part pure carbolic acid (phenol) to 500 parts sirup. This drug had been used, however, in the treatment of bee diseases before Cheshire recommended it. In expressing his apparent confidence in carbolic acid as a cure for foul brood, he writes:

I could take an apiary beginning of March with every stock diseased, and by May 1, with but very little labour, deliver it up clean and strong, as strong as though the disease had never appeared.

Naturally many practical bee keepers who had had experience with foul brood hesitated to accept literally such a broad statement.

CHESHIRE, AUGUST 15, 1884.

The idea which many bee keepers have that a queen with diseased ovaries will transmit the disease to the brood is largely based upon the writings of Cheshire.¹ In a paper he relates his observations in support of his belief that the queen may be responsible for foul brood in a colony. He received from a bee keeper a queen, nearly dead, that was taken from a colony in which some of the larvæ seemed to die immediately after hatching. One ovary from this queen, which was yellow and soft, was removed. A portion was examined under a microscope, and four or five bacilli were observed. Detaching now a half-developed egg, it was placed in a little water upon a slide and covered with a cover-glass. Upon examination, no less than nine bacilli were seen. The right ovary, it is stated,

¹Cheshire, Frank R., August 15, 1884. Queen and eggs containing *Bacillus alvei*—foul brood (?) British Bee Journal, Vol. XII, No. 152, pp. 276-277.

was nearly free from disease. After a long search only two or three bacilli were found in this latter ovary. Cheshire now believed, apparently, that he had demonstrated the disease in young larvæ, in older larvæ, in pupæ, in drones, in workers just gnawing out of the cell, in young nurse bees, in old, worn-out bees, and finally in the queen and eggs unlaidd. Such data as are offered here by Cheshire, of course, are insufficient to prove any etiological relation of a bacterium to a disease.

CHESHIRE, SEPTEMBER 1, 1884.

In an earlier paper (p. 19) Cheshire adhered to the view held by Dzierzon and others, that foul brood was of two kinds.

The view which he expresses in a later article¹ is that there is but one disease and that one is caused by *Bacillus alvei*. After he had examined a number of samples of comb affected with the disease he reached the conclusion that Dzierzon was in error in asserting that there were two kinds of foul brood, one mild, the other malignant. While all cases of foul brood, he says, are due to *Bacillus alvei* and to this extent are identical, yet in some cases the spores of this organism are larger, more robust, and more virulent than in others. When the disease manifests itself early in the development of the brood he contends that it is more difficult to cure, if any difference exists, than when the symptoms appear later in the disease. He contends further that if this disorder is due to the disease lurking in the queen she must be removed.

The doubt that was entertained as to the effectiveness of the carbolized sirup treatment caused Cheshire to perform another experiment. In a healthy colony he placed, on August 6, six combs secured from more than one source, and all affected with foul brood. On the following morning he poured medicated sirup into the combs. Similar feedings were continued daily in liberal quantities until the sixth morning. After this a tin-pan feeder was used, which was not allowed to become empty of sirup. Eggs were laid and brood reared in the foul-brood combs which had been inserted. Almost all the larvæ that were reared were healthy. Many of those that were near the lower edge of these frames, however, were affected and passed through the first stages of the disease. These larvæ later disappeared by being carried out, it was supposed, by the workers. Only three or four sealed cells with diseased brood now remained, and it was believed that these would be cleaned out by the bees as soon as the cappings were broken. With these exceptions, he says, the hives were, on August 23, as perfect as could be desired. Following the description of his experiment, Cheshire writes:

¹ Cheshire, Frank R., September 1, 1884. The Cheshire treatment of *Bacillus alvei* (foul brood). British Bee Journal, Vol. XII, No. 153, pp. 294-296.

The Bee Keepers' Record says, in referring to my paper, "Whether phenol is really a specific for foul-brood time alone will show, but we urge our readers to give it a thorough trial." I reply that all that could be done to prevent phenol succeeding I have done. I have heaped up difficulties: given bees such combs as I venture to say they have never received before in the history of bee keeping; secured the most virulent type of the disease I could discover, and yet in seventeen days a most perfectly healthy aspect is presented, and the bees, with brood in their six frames, are hard at work comb-building. I assert, with all the positiveness I can command, that phenol, upon my plan, is a specific, and only needs a careful and correct application.

Bee keepers who have had experience in the treatment of foul brood can decide, first, whether such phenomenal results as Cheshire has recorded are to be expected, and, second, whether from one experiment like this he should have asserted so positively that the method is a specific one.

The method advocated by Cheshire was given a trial, however, by many bee keepers, especially in England. To indicate what harm might ensue from such immature work, we quote from a few who followed his advice. A questioner¹ gives the following from his experience:

Having used carbolic acid as a prophylactic in the apiary for more than fifteen years, I was delighted to learn that Mr. Cheshire, by putting a little amongst syrup and pouring it into the brood-cells of a virulently diseased stock, had succeeded in effecting a complete cure. To test its power in this way I procured a bottle of medicated material prepared under Mr. Cheshire's guarantee, and began to treat a stock, thoroughly foul-brooded, according to the method prescribed—on the 30th August last.

Circumstances were all favourable, such as a high temperature, a breeding queen, and bees carrying in pollen. No heat was allowed to escape from the stock through imperfect covering. But although the treatment has been carried on till now (Oct. 20th), there is no more abatement of disease than usually takes place when egg-laying becomes languid. The population is getting reduced; the cells perforated and closed are filled with gluey, putrid matter, and the stench emitted is scarcely less offensive than formerly.

What the treatment can effect in spring and summer, when greater heat and activity prevail, remains to be tested; but from what has come under my observation I have come to the conclusion that unless the apiarian himself clear out every foul cell, no virulently diseased hive can be restored to perfect health in the autumn by administering phenol as Mr. Cheshire directs.

From another bee keeper² we quote the following:

I have used Mr. Cheshire's cure, and followed his directions to the best of my ability, but it has proved in my case a complete failure.

From another³ the following is quoted:

During the latter end of July I observed that three of my bar-frame hives were affected with foul brood. I was a little puzzled what to do, as I never had had any

¹ Questioner, November 1, 1884. Phenol no cure in autumn. *British Bee Journal*, Vol. XII, No. 157, p. 379.

² Johnston, Arthur B., November 1, 1884. Is phenol a cure for foul brood? *British Bee Journal*, Vol. XII, No. 157, p. 379.

³ Veritas, November 15, 1884. Foul brood. *British Bee Journal*, Vol. XII, No. 158, pp. 399-400.

experience of nor had I seen the disease before. However, from the confident way in which Mr. Cheshire spoke of his phenol cure, I resolved to try it, and as honey was still coming in, I had to pour the medicated syrup over the brood-combs; but as soon as the ingathering of honey ceased, I extracted all the combs in my apiary and commenced to feed; and after a little experience of it, I found that 1 in 600 was as much as the bees would take. When enough of this had been deposited and sealed for winter stores, I made a thorough examination, and found that it had not cured a single one, but the disease had spread to others that were being fed with the carbolised syrup. I then withdrew the combs from two of the worst, and gave them empty ones to begin in, re-fed them 1 in 600 of Calvert's No. 1; the disease spread again, and I lost all faith in the Cheshire cure.

CHESHIRE, SEPTEMBER 15, 1884.

Two weeks later another article¹ by Cheshire appeared in which the origin of the names *Bacillus depilis* and *Bacillus gaytoni* is found.

Many cases had been reported in which numerous small, hairless bees had been found in front of the hive. These had been considered simply as robbers. It seems, however, that Miss Gayton, a bee keeper and observer, had furnished Mr. Cheshire some of these bees, together with her notes for examination. He examined the bees and found in them in every case a bacillus smaller than *Bacillus alvei*, and by work done in the Biological Laboratory at South Kensington they were believed to be entirely distinct species. In his paper Cheshire writes:

This bacillus, undoubtedly, produces this effect [premature baldness] and so again I claim the right of giving a name, and so suggest *Bacillus depilis*, or the bacillus of hairlessness, as a fitting one. Although, perhaps, *Bacillus gaytoni* would be better remembered and only a well-deserved compliment.

Here again it is noted that data are wanting to justify the conclusions drawn.

Cheshire in the same article gives also a few laboratory notes of some interest to support his view that *Bacillus alvei* is the cause of foul brood. He, together with Cheyne, inoculated some gelatin tubes with a small quantity of the coffee-colored remains of diseased cells. Subcultures to the seventh generation were made. The character of the growth thus obtained indicated that the organism was unknown. The cultures were described as having the same characteristic odor that is encountered in hives containing foul-brood material. This he believed to be strong evidence that *Bacillus alvei* is the cause of foul brood. In this same paper he anticipated the proof to be obtained from the inoculation of a healthy colony with *Bacillus alvei*. The twelfth generation of the culture was to be mixed with water and sprayed over a card of healthy brood. Concerning the results to be obtained he writes: "I will not prophesy, although I foresee the results." At that stage of his investigation it was unwise, of course,

¹ Cheshire, Frank R., September 15, 1884. Bee diseases in relation to apiculture and general science—*Bacillus gaytoni* (?). British Bee Journal, Vol. XII, No. 154, pp. 317-318.

to entertain such hopes. It might at first seem to the reader that Cheyne was jointly responsible with Cheshire in these statements, but it will be learned later that the responsibility is with the latter.

CHESHIRE, OCTOBER 15, 1884.

In another paper¹ which appeared one month later, Cheshire considers the possibility of the transmission of foul brood from drones at the time of mating. He received from a bee keeper a queen that had accompanied a swarm, and after beginning to lay for the new colony she ceased after about 6 square inches of comb had been filled and never laid again. Upon post-mortem examination the ovaries and spermatheca were apparently normal to the naked eye. The contents of the spermatheca were examined under the microscope and many bacilli were found among the spermatozoa. An inflamed condition of the mucous gland and valves was reported to be present, and this fact was given as the probable reason why the oviposition had been arrested. The theory advanced by Cheshire to account for the disease was that the colony had recently cast a swarm unobserved, and that the queen which had been sent him for examination was a young one and in mating had contracted from the drone the condition that was observed microscopically. This supposition seemed probable to him, because he had seen what he identified as being *Bacillus alvei* among the spermatozoa of drones taken from foul-brood colonies.

Cheshire cites another case: A queen had been sent to him with the information that she was an old one. Upon examination he concluded, on the contrary, that she was young and badly diseased, since among the spermatozoa, as in the first case, many bacilli were observed. Naturally from such observations Cheshire did not prove that the cause of foul brood could be transmitted from drone to queen at time of mating.

CHESHIRE AND CHEYNE, AUGUST, 1885.

The paper which was prepared by Cheshire and Cheyne² conjointly, as the result of the work mentioned in this quotation, was read on March 11, 1885, and was published in August, 1885. It appears in two parts. Part I, written by Cheshire, considers the pathogenic history of "*Bacillus alvei*," and Part II deals with the history of *Bacillus alvei* under cultivation, which is the portion written by Cheyne. The part written by Cheshire contains a sum-

¹ Cheshire, Frank R., October 15, 1884. A new discovery with regard to bacillus disease. Diseased spermatheca. British Bee Journal, Vol. XII, No. 156, pp. 355-356.

² Cheshire, Frank R., F. R. M. S., F. L. S., and Cheyne, W. Watson, M. B., F. R. C. S., August, 1885. The pathogenic history and history under cultivation of a new bacillus (*B. alvei*), the cause of a disease of the hive bee hitherto known as foul brood. Journal of the Royal Microscopical Society, Ser. II, Vol. V, Part 2, Plates X and XI, pp. 591-601.

mary of his work on foul brood which appeared for the most part in the papers by him which we have already reviewed. In addition to the work contained in his former papers he reports the results of his experimental inoculation of healthy larvæ with cultures of *Bacillus alvei*.

On page 24 of this bulletin it will be noted that Cheshire outlined briefly the manner in which the inoculations would be made, and stated furthermore that he could foresee the results. After obtaining the results of his experimental inoculation, he writes as follows:

It is needful before passing to the second head to anticipate one or two points to which Mr. Watson Cheyne will especially refer. After very many cultivations conducted in series by that gentleman, a small quantity of sterilized milk was inoculated from the last tube. It behaved characteristically, as Mr. Cheyne will describe, the flask emitting upon the drawing of the plug the unmistakable odour so distinctive of the disease in the hive. Some of this milk I diffused through water and sprayed from an atomizer over a healthy comb of larvæ, part of which was protected by a cardboard sheet into which four lozenge shapes had been cut. The larvæ protected matured in health; those exposed to the spray in many cases were removed by the bees, while the rest died, their bodies filled with *Bacillus alvei*. This last experiment seems to complete the chain of evidence in favour of "foul brood" not being accidentally associated with this bacillus, but actually its result.

If positive results can be obtained by experimental inoculation of course such results furnish evidence which is of the greatest value in the determination of the cause of the disease. Cheshire's experiment, however, did not furnish such evidence. It will be noted that Cheshire states that some of the larvæ died with their bodies filled with *Bacillus alvei*, and while he does not say positively that the larvæ died of foul brood, this idea is likely to be inferred by the next statement that is made. While these statements by Cheshire are made with some degree of conservatism, they evidently have been interpreted by many to mean that the disease was produced, and this conception has led to a great deal of confusion in the minds of bee keepers concerning the cause of foul brood. Cheshire states that Cheyne will especially refer to the experimental inoculation of healthy brood which he only anticipates in his part of the paper. In considering Cheyne's contribution it will be seen in what way he disposes of this very important phase of the investigation.

This completes the consideration of the papers by Cheshire as far as we purpose to deal with them at present. Before taking up the investigations of Cheyne on *Bacillus alvei* it may be well to summarize Cheshire's papers on foul brood.

1. Having accepted an invitation from the British Bee Keepers' Association to give an address upon foul brood, Cheshire began to study the disease about the last of May, 1884, although he mentions having examined, microscopically, larvæ dead of the disease some years before.

2. He gave the results of the first two months' work before a conference of this association on July 25 of the same year.

3. Although he started out with Dzierzon's idea that two forms of foul brood are to be encountered in studying the disease in the apiary, he does not seem to have suspected, while making his observations, that probably two distinct diseases were being called by the one name—foul brood.

4. The observations which he made on the morphology of the bacillus found in the diseased and dead larvæ were very good. He probably saw what we now know as *Bacillus larvæ*, but interpreted his findings wrongly. Before Cheshire and after him there were several who probably encountered the same bacillus in their studies, but who made the mistake of misinterpreting their results. Inasmuch as American foul brood is widely distributed in many countries, and *Bacillus larvæ* is always found in the larvæ dead of the disease, it would have been almost impossible for these men not to have seen this microorganism.

5. Cheshire, by his studies on the morphology of the bacillus, by his inoculation experiments on blowfly larvæ, and by cultures, attempted to prove that Schönfeld was in error in his investigations. It is true Schönfeld had not proved his theory concerning the etiology of foul brood, but Cheshire in his attempt to do so failed to prove that Schönfeld was in error.

6. Cheshire began the study of *B. alvei* culturally with a medium prepared from the larvæ of bees. He was unfamiliar, however, with the technique used in cultural methods, and for this reason too much importance should not be attached to his results. Historically, however, it is of interest, since it was probably the first cultural work to be done in the study of bee diseases.

7. Inasmuch as he inoculated healthy brood with cultures, one learns that Cheshire recognized the advisability of making animal inoculations in determining the cause of disease. Unfortunately here, too, the methods he used were deficient, and his interpretation of the results obtained misled many as to the cause of foul brood.

8. Cheshire had suspected from some observations which he had made that adult bees suffered from foul brood. Examining microscopically the content of the intestinal tract of an adult bee taken from a foul-brood colony, he found many active bacilli to be present, and from this observation he was convinced that adult bees, as well as larvæ, suffer from the disease. Had he, however, examined a healthy bee in the same way, he would probably have seen a similar condition.

9. He gave the name *Bacillus alvei* to the bacillus with which he was working. "*Alvei*," used to designate the species, is very similar to the word "*alvearis*," which Preuss used (p. 16) to designate the

species of the microorganism, *Cryptococcus alvearis*, seen by him in foul-brood larvæ. The two may have been the same germ.

10. From his own work there is no way of knowing positively with what bacillus Cheshire was working, since he made no satisfactory description for its identification. Later (pp. 31-33) Cheyne made a careful description of *Bacillus alvei*, and Cheshire agreed that it was the organism to which he had given this name.

11. Cheshire asserted positively that his phenol treatment is a most effective one for foul brood. Many bee keepers have tried it, however, without success.

12. He concluded upon further study that the two forms of the disease described by Dzierzon are one disease, and that this disease is amenable to the "Cheshire treatment," even when the disease appears in the most malignant form.

13. Concerning the difference noticed in samples examined microscopically, he writes that the more robust spores are associated with the more virulent disease.

14. He was led to believe that the "premature baldness" of "black robbers" was due to a bacillus which he saw and named *Bacillus depilis* or *Bacillus gaytoni*.

15. He reported that the odor of a gelatin culture of what he supposed was *Bacillus alvei* was very similar to the odor observed in colonies affected with foul brood. Even if *Bacillus alvei* were the cause of a disease of the brood, one should not expect, of course, this similarity.

16. He suggests the possibility that a queen at the time of mating might become infected with *Bacillus alvei* from a drone reared in a foul-brood colony. He expressed a strong conviction that in this way foul brood might be transmitted to a healthy colony.

17. He would have his readers believe that he had found the disease in young larvæ, in those fully fed, in chrysalids of all stages, in drones, in workers just gnawing out of the cell, in young nurse bees, in old worn-out bees, and in the queen and the unlaidd eggs.

18. All of Cheshire's papers which have been considered—and we have not referred to them all—were prepared in less than one year and most of his observations were made in less than half that time.

We have reviewed these papers by Cheshire in order to point out the origin of some of the errors that have crept into bee literature. That the several suggestions made by Cheshire were never demonstrated to be true will at once be apparent to the reader. The following criticism offered by Cheshire¹ on the work of Schönfeld may now be applied, it seems, with equal propriety to his own:

I cannot refrain from expressing my conviction that it is much to be regretted that so misleading an account of experiments, to all appearances conclusive and complete,

¹ Cheshire, Frank R., August 1, 1884. Foul brood (not Micrococcus, but Bacillus), the means of its propagation and the methods of its cure. British Bee Journal, Vol. XII, No. 151, pp. 256-263.

should have been given to the apicultural world. In their absence, it is hardly possible that we could have all been in the dark so long.

Because of the important bearing which the work of Cheshire and Cheyne has upon the names of the two infectious bee diseases, and upon the names now applied to the bacteria found in the diseased larvæ, it might be well before taking up the work of Cheyne to consider these two men briefly and judge from the evidence at hand their relation to each other.

Cheshire was a man who wrote considerably upon bees and bee keeping, being apparently more or less familiar with the habits, anatomy, and manipulation of bees. From his writings about the diseases of bees, however, one at once suspects that his experience in this line of apiculture was quite limited. His conception of the etiology of diseases in general was evidently very inaccurate. His bacteriological knowledge was wanting. Of this he was undoubtedly aware, as he later intrusted this part of the work to Cheyne, who was then working in a biological laboratory at South Kensington, London.

Cheyne is a man who is familiar with the technique of disease investigation. He was apparently, however, not familiar with the disease, foul brood, at the time he received the sample from Cheshire. This fact, however, does not discredit the actual work which Cheyne did.

If this was the relation existing at that time between these two men, and if this is a correct interpretation of their knowledge, respectively, of foul brood, then it is not strange that Cheyne should have been slightly misled by the opinion of Cheshire on two very important points in his work. These two erroneous ideas which Cheyne evidently gleaned from Cheshire were, firstly, that foul brood was one disease, and secondly, that the disease had been produced by Cheshire experimentally by using pure cultures of *Bacillus alvei*.

CHEYNE, AUGUST, 1885.

Cheyne in his contribution¹ records the first creditable work done on the microorganisms found in foul brood. One observes that Cheshire writes:²

To-day [August 11, 1884] I have been with Mr. Watson Cheyne in the Biological Laboratory, South Kensington, and there we have started some experiments, of which more will have to be said hereafter * * *.

And Cheyne begins his paper by writing:

On August 11, 1884, Mr. Cheshire brought to me a piece of comb containing larvæ affected with foul brood * * *.

¹Cheshire, Frank R., F. R. M. S., F. L. S., and W. Watson Cheyne, M. B., F. R. C. S., August, 1885. The pathogenic history and history under cultivation of a new bacillus (*B. alvei*), the cause of a disease of the hive bee hitherto known as foul brood. Journal of the Royal Microscopical Society, Ser. II, Vol. V. Part 2, Plates X and XI, pp. 581-601. (For the portion written by Cheyne see also Report of the meeting of inspectors of apiaries, San Antonio, Tex., November 12, 1906. U. S. Department of Agriculture, Bureau of Entomology, Bulletin No. 70, June 17, 1907, pp. 23-35.)

²Cheshire, Frank R., August 15, 1884. *l. c.*

The sample of comb which Cheshire gave to Cheyne for examination then was considered by Cheshire to be foul brood, and therefore was thought by the latter to be a sample of the only form of the disease that exists under this name. Further Cheyne writes, "selecting cells which were closed, but which Mr. Cheshire thought contained diseased larvæ, * * *." This statement indicates that Cheyne was unfamiliar with the gross appearance of the disease as it is found in the combs. After uncapping the cells containing foul-brood larvæ, he further writes, "these larvæ were dead, of a yellowish colour, and almost liquid, * * *." Capped cells occur more often in American foul brood, but are not rare in European foul brood. The yellowish color and the almost liquid condition are symptoms which would rather strongly suggest that the sample which he examined was European foul brood. Numerous rods were found microscopically in the diseased larvæ. Cultures were made in gelatin and in agar. The bacteria found in the larvæ and those which appeared in the cultures by comparison seemed to be the same. The morphology and cultural characters of this bacillus (*Bacillus alvei*) were carefully studied.

Concerning the method by which multiplication takes place, Cheyne writes:

The bacilli appear to grow mainly by fission, but I have seen appearances which seem to me only explicable on the supposition that they also grow by sending out buds from one end.

A study of the germination of the spores was made, using the hanging-drop preparation. A drop of bouillon was placed on a cover-glass, inoculated with the spores of *Bacillus alvei*, and inverted over a cell in a glass slide. Preparations made in this manner were placed at a temperature favorable for the growth of the bacteria, and from time to time studies were made of them by the aid of the microscope. He writes:

In three hours the first indication of sprouting of these spores becomes evident. The stained part of the spore loses its oval shape, becomes elongated, and is soon seen to burst through the spore-capsule at one part.

From this it is not possible to know whether he observed the capsule to burst on the side or at the pole, but the figure to which he refers shows the rod bursting through the capsule at or near the pole.

Having studied the germination of the spores, he proceeded to study the formation of the spores in the rod. In doing this two methods were employed. The first was by use of the hanging drop, similar to that used in his study of the germination. By this method he observed in one preparation that most of the rods were beginning to form spores in 23 hours, while in another preparation where more bouillon was used no evidence of spore formation was present during

the first 28 hours. This led him to conclude that the time when spores are produced might depend upon the amount of bouillon used and the number of bacilli present. This caused him to devise a second method. The second method involved the use of a flask of sterile bouillon, which was inoculated with the vegetative form only of the bacillus. This flask was placed in the incubator for two or three hours that the organisms might diffuse equally throughout. The flask was then shaken, and by means of a syringe gauged on the piston equal quantities of the medium and bacilli were taken. In a series of preparations thus obtained and kept at 36° C. the earliest appearance of spore formation was evident in 41 hours.

Cheyne records the fact that the swelling in the rod which takes place is usually near the center, but sometimes nearer an end. This swelling increases in size at its center and gradually fails to take the stain. The capsule of the spore, he states, is apparently formed within the rod and is not the outer part of the rod. In three or four hours after the spore was formed it was either entirely free from the rod, or the rod still inclosed the spore, but was almost invisible.

Having thus studied somewhat carefully the morphology (size, form, and structure) of *Bacillus alvei*, Cheyne took up the further study of the species to determine its cultural characters, stating at this point, very properly, that the microscope is of little use in determining the relation of the bacillus to foul brood. The technique which he used in making cultures is very similar to that used in general bacteriological work at the present time, the chief difference being that now additional differential media are used.

DESCRIPTION OF *BACILLUS ALVEI*.

The following is an abridged description of *Bacillus alvei* as given by Cheyne:

Occurrence.—Isolated from larvæ said by Cheshire to be affected with foul brood. As far as is at present known it has not been found elsewhere.

Gelatin plates.—Gelatin plates were inoculated by stroking the solidified medium with the needle. From small masses of growth, which soon form along this line of inoculation, bacilli in Indian file, or two or three side by side, grow out into the gelatin. These outgrowths are not straight, but tend to curve, and at a short distance from the track of the needle they grow round so as to form a circle. From such a circle other fresh circles may be formed. The growth about this line increases, filling up the center of the circle. These circular growths increase and may join one another, forming a curved anastomosis. The gelatin in the immediate vicinity of the growth

liquefies, and in these liquid channels the bacilli swim to and fro. Later some of these channels are apparently deserted of bacilli, so that the circles may look as though they were detached from the main track. Under low powers, however, the connection between them can be traced.

If the gelatin is inoculated before pouring the plate, the growth which takes place is also very characteristic. At first the colonies are small and oval or round. Under a low power of the microscope the colony does not appear homogeneous, but lines indicating the bacilli are seen. The colony soon becomes pear-shaped, and processes grow out from the sharp end of the pear into the gelatin.

Morphology: Rods.—In the larval juices they are rounded or slightly tapering at the ends, and often have a clear space near one end. Their average length is about $3\frac{1}{2} \mu$. On agar the rods are always somewhat pointed at the ends and varying in size. The average length is about $3\frac{1}{2} \mu$ and the breadth about $\frac{5}{8} \mu$. At the beginning of spore formation the rods begin to swell and become spindle shaped. This increase in diameter is generally near the middle, but sometimes it is seen near one end. The capsule of the spore is apparently formed within the rod, and is not merely the outer portion of it. *Spores.*—The spores are oval, averaging nearly 2μ in length and nearly 1μ in breadth. Spores from agar cultures are generally arranged side by side in long rows.

Motility.—The bacilli swim with a free oscillating movement.

Bouillon.—Growth takes place readily, causing a cloudiness of the medium and the formation after a few days of a slight but not tenacious pellicle. The odor is similar to that described under gelatin. This character is more marked when considerable peptone is present. Probably there is no change in the chemical reaction.

Agar.—The growth is not nearly so characteristic as in gelatin. It takes place most rapidly on the surface, forming a whitish layer. Here the bacilli arrange themselves side by side and, forming spores in this position, there are after a few days, as a consequence, long rows of spores lying side by side.

Blood serum.—Growth takes place slowly, forming long filaments and comparatively few spores.

Potato.—At the incubator temperature the growth takes place slowly, forming a dryish yellow layer on the surface. It is very slow at lower temperatures.

Milk.—Growth takes place readily and coagulation occurs. The medium assumes a yellowish color and gives off the odor present in gelatin-tube cultures. The coagulation is not firm, but like tremulous jelly and may remain so for a considerable time before the sep-

aration of any fluid takes place. Ultimately, however, it becomes liquid, and after some months it assumes the appearance of a dirty brownish yellow, glassy fluid. It is very slightly, if at all, acid.

Gelatin tube.—In this medium the growth is seen on the surface and along the line of inoculation. On the surface a ramifying growth takes place from the point of entrance of the needle; and along the line of inoculation whitish, irregularly shaped masses appear, which increase slowly in size. In a few days processes, which are thickened at various points and clubbed at the ends, shoot out from these masses. The ends of these processes do not seem to unite. A beautiful appearance is obtained when only a few bacteria are introduced along the line of inoculation. In a few days small round colonies become visible to the naked eye. These increase in size, and at about the tenth day shoots begin to appear, which radiate in all directions from the central mass and become clubbed. As the culture becomes older the radiating branches disappear, and only small whitish collections of bacilli are seen at various points. Under slight magnification, however, tracks of liquefied gelatin are seen extending from the central mass to the whitish collections. The evaporation which takes place at the top gives rise to the appearance of an air bubble.

Beginning at the top the liquefaction of the gelatin advances slowly downward until ultimately the entire tube is liquefied. After two or three weeks there is a layer of liquid at the upper part, with the growth as before described in the lower part. At first the liquefied gelatin is clear excepting a loose, white, flocculent sediment which is present. There may be a thin surface pellicle. Later the liquid becomes yellow, and gives off an odor similar to stale but not ammoniacal urine. This, Cheyne says, may better be described as a "shrimpy" smell. "The yellowish color and the peculiar odor," Cheyne writes, "has been found by Cheshire to be distinctive of diseased larvæ."

Cheyne made also a few observations with animals inoculated with *Bacillus alvei*. A bluebottle fly which had eaten some of a milk culture of *Bacillus alvei* was placed under a funnel; the next day it was found dead, and upon examination its juices were reported to be full of the bacilli. Cockroaches were placed in a box with cultures, but none of them died. A rabbit, some mice, and some guinea pigs received cultures of *Bacillus alvei* subcutaneously, but in general only negative results were obtained.

A conclusion which Cheyne drew indicates that at that time he was pretty thoroughly convinced that *Bacillus alvei* was the cause of fowl brood. The belief which he entertained was based upon his

study of *Bacillus alvei*, together with the experiment by Cheshire in which healthy brood was inoculated with a spray containing a culture of *Bacillus alvei*. In drawing the conclusion Cheyne evidently supposed that Cheshire had produced the disease experimentally. Had Cheyne known, on the other hand, that this had not been done by Cheshire, his conclusion would have been undoubtedly differently expressed.

The description which Cheyne made of *Bacillus alvei* is very good. It contains, however, a number of statements with which he, himself, no doubt at the present time would disagree. Such might be expected since it has now been 26 years since he did the work.

There is much data in Cheyne's paper of interest and value. The following is a brief summary of his work:

1. He received a sample of diseased brood from Cheshire on August 11, 1884, and the paper which contained the results of his work was read on March 11, 1885.

2. He described carefully and accurately the morphology and cultural characteristics of *Bacillus alvei*. His description of the organism is the first one by which the identification of the species was made possible.

3. The larvæ which he examined were yellowish and almost liquid. This suggests European foul brood.

4. He found *Bacillus alvei* in large numbers in all the larvæ examined. This, too, suggests European foul brood.

5. He does not mention either the presence of ropy coffee-colored larvæ or scales in the sample examined. This suggests that he was not studying American foul brood.

6. He evidently did not encounter *Bacillus larvæ*, since he does not mention the presence of any bacteria in the larvæ which would not grow on artificial media. This, too, is very strong evidence that he was not studying American foul brood.

7. He was misled by Cheshire's inoculation experiment with bees, causing a statement to be made in his conclusion which was less conservatively expressed than it would otherwise have been.

While Cheshire and Cheyne did not prove the cause of any disease of bees, their work is of importance in determining to what species of bacteria the name *Bacillus alvei* belongs, and also in determining the names for the different brood diseases. The microorganism which Cheyne so well described has the right to the name *Bacillus alvei*, because the species was first described by Cheyne and his work had the sanction of Cheshire, who first used the name.

It is quite certain that Cheyne was working with the disease now known as European foul brood when he secured the data for his

paper, because his description of the larvæ dead of the disease in the sample which Cheshire gave to him as foul brood was quite good for European foul brood and not good for American foul brood; because *Bacillus alvei* was found in sufficiently large numbers to lead these men to suspect that the organism was the cause of the disorder; and because no other species was mentioned as being present in numbers sufficient to cause suspicion of a casual relation. All must agree that if Cheyne did not work with a sample of European foul brood in the preparation of his paper, his work can not be given the credit which it seems to deserve.

McLAIN, 1887.

A paper by N. W. McLain,¹ containing a discussion of bee diseases, was written in the form of a report on some work done by him. The first disorder which he considers is referred to as the "quaking disease." It was thought by McLain that bees would visit milkweed and mullein to obtain from the sap of these plants certain salts as food, if such salts could not be obtained from the ordinary sources. In so doing, thousands of bees lost their lives before, as well as after, reaching the hives. By examining such bees under a microscope, many were found to be entangled in filaments derived from the sap of the plants visited, and with empty stomachs. The peculiar nervous motions made by these starved and weakened bees in their effort to disentangle themselves from the meshes of the fibers is one manifestation of the condition known as the "quaking disease." Another form of this disease was supposed to be of hereditary origin, since it was believed that by removing the queen from an affected colony and introducing a young, vigorous one the trouble would disappear. A third form of the disease mentioned had been reported to be due to the use of poisonous nectar from such plants as foxglove (*Digitalis*).

McLain therefore placed at least three distinct abnormal conditions under the name "quaking disease." He writes definitely concerning the cause of the first condition only. The second condition is probably that which is now known as paralysis, and the third condition, that of poisoning, is occasionally reported by bee keepers as a cause of trouble in the apiary. Very little is definitely known at present concerning any of these disorders. In the treatment of the first condition mentioned he used a drug and reported success.

McLain also made a report on foul brood. Having spoken of the gravity of the disease he writes that he had during the year given much attention to the study of the disease and to experiments for its prevention and cure. That the disease was contagious appeared to

¹ McLain, N. W., 1887. Report on experiments in apiculture. Report of the Commissioner of Agriculture for 1886, pp. 583-591. Washington: Government Printing Office.

him to be certain. The origin and the means of its transmission, however, were not entirely clear. That the germs of the disease may be carried from apiary to apiary upon the clothing of the apiarist and in or upon the bodies of bees, that in the same apiary these germs may be borne by the winds from one hive to another, and that they may be liberated from the decomposing bodies of other insects and scattered to objects with which the bees come in contact, seemed to McLain to be probable. It appeared to him that foul brood attacked adult bees as well as brood, that live pollen is the medium by which the contagion is most commonly and most rapidly spread, and that the disease yields readily to a drug treatment.

In discussing the idea that the clothing and hands of an individual going from one apiary to another might probably be a means by which disease germs are transmitted, he writes:

That the disease germs may be carried upon the clothing and hands appears probable, from the fact that in one neighborhood the disease appeared in only two apiaries, the owners of which had spent some time working among diseased colonies at some distance from home, while other apiarists in that locality who had kept away from the contagion had no trouble from foul brood.

In support of his supposition that the wind might be considered as a medium by which the germs of the disease may be carried, he writes:

That the contagion may sometimes be borne from hive to hive by the wind appears to be true, as it was observed in one of the apiaries which I treated for this disease during the past summer that of a large number of diseased colonies in the apiary, with the exception of two colonies, all were located to the northeast of the colony in which the disease first appeared. The prevailing wind had been from the southwest.

The report covers the work done by McLain in one year on bee diseases. He was conducting at the same time some experiments relative to the control of the mating of the queen. Most of his conclusions concerning diseases were drawn, apparently, from three experiments performed by an apiarist who reported his results to McLain.

The following is a summary of his report pertaining to bee diseases:

1. He made no pretense at a study of bee diseases bacteriologically.
2. He included at least three distinct conditions in the disease of adult bees which he referred to as "quaking disease."
3. He probably included in the "quaking disease" the disorder which is now known to many bee keepers as "paralysis."
4. He recognized the virulence, wide distribution, and, consequently, the destructiveness of foul brood.
5. He probably was not aware that at least two infectious diseases of bees were being referred to as foul brood.
6. Since American foul brood has been the prevailing disease in the region in which his experiments were made, and since the descrip-

tion which McLain gives of the appearance of the dead larvæ is that of American foul brood, he very probably was working with this disease.

7. He seemed to accept the belief that adult bees are affected with foul brood as well as the brood.

8. He supposed that pollen is the medium by which the infection is usually transmitted.

9. He evidently believed in the efficiency of the drug treatment of bee diseases.

Let us now consider for a moment some of his contentions. One must agree with McLain that the diseased condition then known as foul brood is an exceedingly serious one, causing great loss to the bee keepers. That the disease is quite infectious has often been demonstrated. That the germs of the disease may be carried from one hive to another in and upon the bodies of the bees seems very probable. That the germs are carried from one colony to another upon the clothing of the bee keepers and that the infection is transmitted in this way is extremely improbable. That the germs are carried by the winds from one hive to another in the apiary is likewise very improbable. That the germs of the disease are liberated from other insects and afterwards taken up by bees is not probable.

In many ways this report by McLain is a conservative one. Sufficient evidence was wanting to prove most of the points in his paper. He probably realized this fact, and for this reason, as a rule, he did not make positive statements. Inasmuch as his report covers the work of a single season, very little definite information could be expected.

McLAIN, 1888.

In his report ¹ on the succeeding year's work McLain discusses somewhat again the question of bee diseases. This report shows the influence of Cheshire's writings, since McLain now speaks of the inappropriateness of the name foul brood (p. 21) and the certainty of the etiological relation between *Bacillus alvei* and the disease (p. 20). Furthermore he refers to the statements of Cheshire concerning the probable spread of disease through the air and by means of the clothes and hands of the operator, and says that Cheshire's observations are in agreement with his own which he included in the preceding report.

McLain had expressed (p. 36) his firm belief in the theory that pollen was the common source of infection in foul brood, and not honey, as was commonly supposed. This view, he thought, was strengthened by some statements which Cheshire made. McLain was of the opinion that undue importance was being attached to honey as a medium through which the infection is transmitted, and

¹ McLain, N. W., 1888. Report on experiments in apiculture. Report of the Commissioner of Agriculture for 1887, pp. 170-178. Washington: Government Printing Office.

expressed his convictions that there was but little doubt that pollen is the medium by which the contagion is most commonly introduced, most rapidly spread, and most persistently perpetuated.

McLain also includes in his report some remarks on starved brood, and in referring to the symptoms states that in this condition the brood is frequently found to be only partially capped, giving the appearance commonly designated by the term "baldheaded brood."

In estimating the value of this work by McLain, it must be borne in mind that McLain had evidently a very indefinite conception of the phenomena which are encountered and must be dealt with in the study of disease; that he devoted but little time to the study of the disease he referred to as foul brood, and that he was probably unduly influenced by the writings of Cheshire. For these reasons it is advised that his reports be not taken too seriously.

LORTET, FEBRUARY, 1890.

A paper¹ by Dr. Lortet concerning some of the bacteria encountered in the study of foul brood appeared in 1890. He found two species always present in the digestive tract of healthy adult bees as well as in those diseased. These species were reported to be present also in the digestive tract of both healthy and diseased brood. The fact was pointed out that these bacteria had probably led some authors into error in their work. The two species were not named nor sufficiently described to make their identification possible. He encountered also, in the digestive tube of brood diseased and dead of foul brood, another species which he supposed was *Bacillus alvei* and which was the cause of the rapid death of the larvæ. Lortet records no difficulty in cultivating this species on the ordinary media.

It was his belief that adult bees suffered from the disease, but that they resisted the infection more than the larvæ, and finally died as a result of the infection. Experimentally, he claims to have obtained positive results in support of his views. He examined one queen taken from an infected colony and from a study of her he reported that she was perfectly healthy and that her eggs were free from bacteria. It was his opinion that food was the source of infection of the digestive tube of the nurse bees and that the nurse bees became in turn the source of infection for the brood.

From his work he drew the following three conclusions: (1) That Cheshire had found the true exciting cause of foul brood and declared that the fact had been verified by numerous laboratory experiments; (2) that it is useless to attempt to save larvæ already infected, and (3) that adult bees which become infected may live a long time, and some may even resist the attack completely.

¹ Lortet, Dr., February, 1890. La bacterie loqueuse. Traitement de la loque par le naphthol β . Revue Internationale d'Apiculture, Tome XII, No. 2, pp. 50-54.

Believing that the digestive tract of the adult bee was the source of infection for the larvæ, he recommended, as the most rational treatment, the use of an intestinal antiseptic in the form of sirup medicated with beta naphthol, a drug which had been used for some time as an intestinal antiseptic in the practice of human medicine. The feeding of sirup medicated with beta naphthol (one-third gram beta naphthol to 1,000 grams of sirup), he reports, was sufficient in his experiment to free the intestinal tube of the bacteria causing the trouble. This cure he supposed took place rapidly and completely except when the bacteria had reached more completely the different portions of the alimentary tract.

One observes that the views entertained by Lortet on bee diseases are quite different from those entertained at the present day concerning these disorders.

MACKENZIE, DECEMBER, 1892.

In 1892 Mackenzie read a paper¹ on *Bacillus alvei* which he had prepared at the request of the Bee Keepers' Union of Canada. The relation which was supposed by Mackenzie to exist between foul brood and *Bacillus alvei* is shown in the following brief review of his paper:

He received from a bee keeper some samples of diseased brood for examination. He began the study of these samples upon the assumption that Cheshire and Cheyne had already found *Bacillus alvei* and by inoculation with pure cultures had demonstrated this organism to be the cause of the disorder. By finding an organism which he thought from its morphology and cultural characters was *Bacillus alvei*, the conclusion was reached that the samples were foul brood, the same as was found in other places.

Laboring under the erroneous conception that *Bacillus alvei* is the cause of the foul brood prevalent in Ontario, Mackenzie proceeded with the study of the bacillus identified by him as *Bacillus alvei*. The first task mentioned in his paper which was undertaken by him was the solution of the question whether in the making of wax foundation sufficient heat is applied to destroy the vitality of the foul-brood spores. After receiving replies from different foundation manufacturers concerning the highest temperature reached in the process and the time the wax was kept at this temperature, and after making some determinations of the thermal death point of the spores of the bacillus, he writes: "I am inclined to think there is little danger from foul brood in that direction." He found by a cultural method

¹ Mackenzie, J. J., B. A., December, 1892. The foul brood bacillus (*B. alvei*); its vitality and development. Eighteenth Annual Report of the Ontario Agricultural College and Experimental Farm, pp. 267-273.

This address is quoted in full in the Report of the Meeting of Inspectors of Apiaries, San Antonio, Tex., Nov. 12, 1906. (Bulletin No. 70, Bureau of Entomology, U. S. Department of Agriculture, 1907, pp. 36-42.)

that 2 per cent carbolic acid would not kill the spores of *Bacillus alvei* in six hours, and concluded that carbolic acid in this strength could not be relied upon as a hive disinfectant to destroy the spores of this organism.

Mackenzie says that if the shaking treatment is employed, the question of the presence of *Bacillus alvei* in the workers, queen, and eggs must be considered in the discussion of the value of such treatment. He claims to have confirmed the results obtained by Cheshire that the bacilli are sometimes found in the intestine of the worker and the ovaries of the queen, but that the finding of the bacillus in the eggs of an infected queen needs confirmation.

He reports an experiment from which he concluded that carbolic acid (1-500), as used in medicated sirup in the treatment of foul brood, does not kill the spores but prevents their germination, and thus gives the bees a chance to rid themselves of the infection. "Its advantage," he writes, in comparing it with a shaking method, "is that it can be carried on for a longer time." Concerning beta naphthol, he concludes that a 1-1,000 solution in bouillon possesses the same value as an antiseptic as a 1-500 solution of carbolic acid and he believed that it would probably be more acceptable to the bees. The use of salicylic acid was thought by him to be followed by about the same results as carbolic acid and beta naphthol in the medication of sirup. For the cleaning of hives and frames he recommends a 10 per cent solution of soft soap or washing powder.

The following points of interest are found in Mackenzie's paper:

1. He accepted the work of Cheshire and Cheyne as demonstrating conclusively that *Bacillus alvei* is the cause of foul brood, and used in his laboratory experiments a bacillus which he identified as this organism.

2. At the time Mackenzie's paper was written his work on foul brood had been carried on for only about a year, and he appreciated the fact that his work was by no means complete.

3. From the report of foundation manufacturers and from the results of his own investigations, he was inclined to believe that there is but little danger of infection from foundation made from wax taken from a foul-brood colony.

4. He isolated *Bacillus alvei* from the ovaries of three of the five queens examined, but believed that the findings of Cheshire with respect to the eggs need confirmation.

5. He interpreted the finding of *Bacillus alvei* in the intestines of workers and queen as a fact worthy of consideration in the shaking treatment.

6. He believed that drugs in the treatment of foul brood have a value in preventing the germination of the spores.

The greatest mistake made by Mackenzie in his work was of course that he assumed that *Bacillus alvei* had been demonstrated to be the cause of foul brood.

The work which Mackenzie began was to have been continued the following summer, but, in a report¹ of the Apicultural Committee of the Ontario Agricultural and Experimental Union one notes that Mackenzie, who had the preceding year given his services in connection with foul brood, for the want of time had not continued his studies.

HOWARD, MARCH 1, 1894.

In 1894 there appeared from the pen of William R. Howard,² of Fort Worth, Tex., a small publication on foul brood. He makes clear in his preface that there is yet much to be learned upon the subject, and that his communication is to be written in such a manner, and such terms are to be used in it, as will be readily understood by the general reader.

In his brief reference to the history of foul brood, Howard writes:

Later the researches of Preuss and Schönfeld, of Germany, were first to establish the fact that the disease was due to pathogenic micro-organisms.

Howard, therefore, in the beginning entertained an erroneous conception concerning the real work accomplished by Preuss (p. 15) and Schönfeld (p. 16).

The description given of *Bacillus alvei* was taken, as he says, from "Eisenburg's Bacteriological Diagnosis." The description of *Bacillus alvei* by Eisenburg was compiled from the joint publication by Cheshire and Cheyne (p. 25). Howard made some determinations concerning the ability of the species to produce gas and the ease with which it grows in the presence or absence of oxygen. He reports that the cultures, when grown under anaerobic condition, produce an odor resembling foul brood. Eisenburg does not include in his description any mention as to the oxygen requirements of *Bacillus alvei*. The only difference, it seems, between the description which Cheshire and Cheyne made of *Bacillus alvei* and the conception which Howard had of it, is in the fact that Howard thought that it grows better under anaerobic conditions, while Cheshire and Cheyne obtained very satisfactory growth on the surface of media exposed to the air.

Propositions are stated by Howard in his paper, and his own interpretations of them are given. Some of his views can be accepted as good, others can not.

¹ Holtermann, R. F., Monteith, S. N., Husband, E. M., 1893. Report of Apicultural Committee. Fifteenth Annual Report of the Ontario Agricultural and Experimental Union. Pp. 230-231. Contained in Nineteenth Annual Report of the Ontario Agricultural College and Experimental Farm.

² Howard, Wm. R., M.D., March 1, 1894. Foul brood; its natural history and rational treatment, with a review of the work of others. Chicago, Ill. Pp. 47.

His reference to the gross appearance of the disease material with which he was working strongly suggests that the disorder was American foul brood. In every case that he examined he reports the presence of *Bacillus alvei*.

HOWARD, SEPTEMBER 10, 1896.

Having gotten Howard's conception of foul brood and *Bacillus alvei*, we shall pass to another paper¹ by the same writer.

The term "pickled brood," which is often used by bee keepers, had its origin apparently in an article by Howard in which he reported a condition in the brood of bees as a new disease. Since the term "pickled brood" is so frequently used in beekeeping literature it may be well to consider Howard's work somewhat in detail.

The trouble which he calls pickled brood he says had often been mentioned by writers in bee papers. Two years before his paper was written he himself had two colonies to die during the winter, and when in the spring the combs were examined they were found to be moldy, especially those containing pollen. These combs were given to other colonies with no bad results, until the brood which was being reared was about ready to be capped. By watching this brood he observed that it did not decay like "foul brood." When the larvæ are dead, he says, they have a swollen appearance, with neither end touching the cell as a rule. After a few days some of the larvæ settle down and change to a dark brownish mass which is watery, not ropy, and without odor.

From the combs and dead brood there was isolated a species of fungus to which he ascribed the cause of the trouble, and to which he gave the name *Aspergillus pollini*. Concerning his convictions as to the etiological relation existing between the fungus and the disease he writes: "Several experiments were made during the summer which fully satisfied me that my conclusions were correct." This condition suggested to Howard the possibility of its being the form of foul brood which responds to the shaking treatment and the drug method, and the form which disappears of itself when fresh pollen is consumed by the bees. He says that the fungus finds a good medium in food which contains pollen in the alimentary canal of the larvæ. The fungus, he says, breaks through the wall of the alimentary canal, permeates all the liquids of the body, and there produces acetic acid. The larva dies in about three days and is pickled in its own juices containing this acetic acid. Such a supposition suggested to Howard "pickled brood" as a name for the disease. On account of the acid reaction of the larvæ thus "pickled," he believed that no putrefactive germs entering from the air could grow

¹ Howard, Dr. Wm. R., September 10, 1896. A new bee-disease—pickled brood or white fungus. American Bee Journal, vol. 36, No. 37, pp. 577-578.

and cause putrefaction of the tissues, and for this reason no odor was present. He includes in his paper a differential diagnosis between foul brood and pickled brood.

In foul brood, he says that the brood is attacked at all ages, from two to three days after hatching until after it is capped, and that as much brood dies before the feeding of pollen as afterwards; that the brood is attacked by the putrefactive germs from the air, causing rapid decomposition, resulting in a ropy brownish mass that gives off a very foul odor; that the cappings of the sealed cells are usually ruptured by the gases generated within the cell, and that the larvæ are found in a shapeless mass lying on the lower side-wall of the cell and closely adhering to it. Furthermore, he says that when gelatin and potato are inoculated with a culture of *Bacillus alvei*, growth at once takes place, forming a viscid ropy liquid which gives off an offensive odor resembling foul brood, and when such cultures are exposed to putrefactive germs a growth of such bacteria takes place.

In pickled brood, on the other hand, he says that the brood is attacked only after the pollen is mixed with the liquid food, and it dies usually just before reaching the pupal stage, but that it may pass into this stage and be sealed before being overcome by death. No brood, he argues, dies before the age of feeding mixed food arrives. Being in this acid or pickled condition, the brood is not attacked by putrefactive germs, and, therefore, no decomposition takes place. There is a watery condition of the brood. The larvæ may be of a light brown color, but generally are white, and no odor is present. The capping is not ruptured in the brood that is sealed. The brood has a swollen appearance, does not stick to the cell wall, and often does not lose its shape. Furthermore, he argues that if brood is placed in a medium of sweetened water in which starch or wheat bran is mixed, and placed in a moist chamber within a dark room, growth of the fungus takes place and covers the surface of the medium. The medium becomes acid, and when such a culture is exposed to the air putrefactive germs do not attack it.

In this paper the following points are observed:

1. Howard used the term "pickled brood" for a disorder which was clearly different from "foul brood."

2. He gave a brief but fairly satisfactory description of the gross symptoms of the condition.

3. He claims that the disease is a specific infectious one.

4. He declares that the cause of the disease is a fungus which he isolated from larvæ dead of the disease and to which he gave the name "*Aspergillus pollini*."

5. The experimental data by which he was supposed to have proven that *Aspergillus pollini* is the cause of the pickled brood,

although not included in his paper, was, as he says, satisfactory to himself.

6. The description which Howard made of the fungus is not sufficient to identify it.

One at once observes that Howard brought forth no convincing evidence that the disorder with which he was working was infectious, nor that the fungus which he named *Aspergillus pollini* was a new one, nor did he prove that any etiological relation existed between the fungus and the disorder.

Inasmuch as the disorder which Howard described was declared by him to be due to a fungus, *Aspergillus pollini*, it is certain that the disease known to bee keepers as pickled brood is not the "pickled brood" of Howard. It is the opinion of the writers that the "pickled brood" described by Howard does not exist.

HOWARD, FEBRUARY 15, 1900.

Another paper¹ by Howard appeared in 1900, discussing still another disease which he supposed was not "foul brood." The disease, as will be learned later, was in all probability European foul brood.

He quotes a description of this disease by Mr. N. D. West, an able bee inspector of the State of New York. In this quotation Mr. West says that the disease appears in the spring about the time the apple is in blossom, breaking out all at once and spreading with amazing rapidity. The young larva has a yellow speck on the body, about the size of a pinhead. The older larvæ are lengthwise in the cell, white, and uncapped. After dying the brood is either removed by the bees or flattens out and becomes at first a cream-colored and later a coffee-colored mass. Later in the season some brood, which had died after capping, becomes coffee colored and of the consistency of heavy honey. When this is tested with a toothpick, the decaying mass stretches out to the extent of one-half inch to 1 inch. In some cases the odor is sour, while in others cases, especially if the capped stage has been reached by the dead brood, it has a somewhat rotten odor. The odor is not especially disagreeable at any time. The colony either dies out entirely from this disease, or the condition improves so that later in the summer no diseased brood can be found. With plenty of stores and a good flow, the disease seems to abate.

Mr. West's many years of experience as a bee keeper, his experience as an inspector of apiaries, and his ardent enthusiasm on questions relating to bee diseases, make his description of the appearance of this disease of much value.

Although Howard quotes from West the symptoms that are found in the so-called black brood, one finds him deviating far from them in

¹ Howard, Dr. Wm. R., February 15, 1900. New York bee disease, or black brood. Gleanings in Bee Culture, Vol. XXVIII, No. 4, pp. 121-127.

stating his own conception of the disease. In giving his own view of the symptoms of the disease, and in pointing out the differences which he supposed existed between "black brood," "foul brood," and "pickled brood," the writings of Howard indicate, as is evidenced by the following quotation, that he himself had a very inaccurate conception of the brood diseases of bees.

SYMPTOMS AND COURSE.

Brood is usually attacked late in the larval life, and dies during pupation, or later when nearly mature and ready to come forth through the chrysalis capping. Even after leaving the cell they are so feeble that they fall from the combs helpless. Most of the brood dies after it is sealed. In this it is much like pickled brood, except that as much or more brood dies in the late larval stage than in the pupa. In foul brood, while brood of all ages dies, yet more dies "at the ages of 6, 7, 8, and 9 days than at any other age" (author's Foul Brood p. 46), even before the rich chyle-like food mixed with pollen is given, which is such a necessary environment for pickled brood and *black brood*.

When the larvæ show the first signs of this disease, there appears a brownish spot on the body, about the size of a pinhead. The larvæ may yet receive nourishment for a day or two; but as the fermentation increases the brownish spot enlarges, the larva dies, stands out, swollen and sharp at the ends. In this they are like pickled brood, except that the brown spot is not present in pickled brood, but pickled brood sometimes becomes brown after death. Foul brood turns brown only after the action of the putrefactive germs have brought about decomposition. No decomposition from putrefactive germs takes place in pickled brood. In *black brood* the dark and rotten masses, in time, break down and settle to the lower side of the cells, as a watery, syrupy, granular liquid—not the sticky, ropy, balsam or glue-like semi-fluid substance of foul brood. It does not adhere to the cell walls like that of foul brood; has not the characteristic foul odor which attracts carrion-flies, but a sour, rotten-apple smell, and not even a house-fly will set her foot upon it. Cappings in foul brood are sunken in the center when broken, sometimes puffed out by internal gases. In *black brood*, the cap is disturbed from without, sometimes uncapped, and cell contents removed by the bees; not so in foul brood. The cap in pickled brood is usually undisturbed. The decayed brood masses do not adhere to the cell walls like either of the others.

The defect in Howard's description of the appearance of the brood which has probably caused the greatest confusion has reference to the color of the larvæ dead of the disease. In the following quotation he mentions the dark and black color of the brood, which according to him was so marked that it suggested the name "black brood."

On account of the character of the dead brood; its beginning with a dark spot on the larva, which increases in size, becomes darker, and finally black, for convenience and brevity the name *black brood* has been suggested, and this name is used in the text.

Since the so-called black brood is in all probability European foul brood, many bee keepers expect to find black larvæ in this disease. Occasionally some of the larvæ may be black, but black larvæ are seldom found. If the bee keeper will bear this fact in mind he will be very much aided in understanding the brood diseases of bees.

From samples of the so-called black brood, Howard reports that he isolated two new species of bacteria. The one he named *Bacillus*

militi and declared it to be the specific germ of "black brood"; the other he named *Bacillus thoracis* and thought probably that it modified the disease in some way. He said so little about either of these species that neither of them can be identified from his writings. In his examination of five specimens received from West, he reports *Bacillus militi* in all of them, *Bacillus thoracis* in two, and *Aspergillus pollinis* in two.

In his experimental investigations Howard used two nuclei which were free from disease, and fed each of them a culture of "*Bacillus militi*" in one-half pint of sirup on November 7, and repeated similar feedings on November 10. The feeders were removed from each hive on November 12. When the bees were examined on November 26, no brood at all was found in one of the nuclei. In the other nucleus was found no eggs, but larvæ six or seven days old and considerable capped brood. Near the outer part of the brood-nest apparently some capped cells were found from which were taken nearly matured pupæ. Other pupæ, nearly white, with a dark spot on the abdomen, were removed, together with others which were dark or black all over. "*Bacillus militi*" was reported to have been found microscopically in nearly every pupa examined. Howard states that no uncapped larvæ seemed from gross appearance to be affected, but in the bodies of several of them *Bacillus militi* was found. The two nuclei were again examined on December 14. As before, there was nothing wrong apparently with one nucleus. In the other nucleus there were about 30 capped cells which contained dead pupæ that were nearly black. Microscopic examination caused him to report the presence of *Bacillus militi* in all of these pupæ.

It will be observed that the results which Howard obtained from the inoculation of the two nuclei with cultures of "*Bacillus militi*" neither proved nor disproved the causal relation of "*Bacillus militi*" to "black brood." As evidence to support his declaration that *Bacillus militi* is the specific cause of black brood, modified probably at times by *Bacillus thoracis*, he offers the data that *Bacillus militi* was found in all of the few samples which he examined, and that in a few instances *Bacillus thoracis* was also present.

In pointing out the differences between "foul brood," "pickled brood," and "black brood," the following three assertions are made by Howard; not one of them, however, has yet been demonstrated to be true.

Foul brood, pickled brood, and black brood. Foul brood, due to *Bacillus alvei*—a specific bacterium.

Pickled brood, due to *Aspergillus pollinis*—a specific fungus.

Black brood, due to *Bacillus militi*, modified, perhaps, by *Bacillus thoracis*, specific bacteria.

Summarizing this paper by Howard the following points might be mentioned:

1. Howard received during the year 1899 a few samples of a brood disease, principally through Mr. West, of New York State.
2. He reported that the disease was a new one and gave to it the name "New York bee disease" or "black brood."
3. From the samples of the disorder he claims to have isolated an organism to which he gave the name *Bacillus milii*.
4. He made no description of "*Bacillus milii*" by which it is possible to identify the organism positively.
5. He claims that "*Bacillus milii*" is the cause of the disorder which he studied, and in support of it he relates some experimental work.
6. He says that "*Bacillus milii*" may be accompanied by another species, "*Bacillus thoracis*," which may assist in the destruction of the brood.

This concludes our consideration of three papers written by William R. Howard.

Reviewing the writings of William R. Howard, one learns that they have caused no small amount of confusion in the minds of bee-keepers respecting the brood diseases of bees. Howard claimed to have found *Bacillus alvei* in that form of foul brood characterized by a ropiness, and asserted that that organism is the cause of the disease. He gave the name "pickled brood" to an apparent disorder of bees which, he says, had often been mentioned in the writings of bee-keepers. He asserts that this "pickled brood" is due to a fungus to which he gave the name *Aspergillus pollini*. He called the disease about which Cheshire and Cheyne had already written (p. 25), "black brood." He declared the disorder to be due to a micro-organism to which he gave the name *Bacillus milii*. The incomplete description which Howard made of the species, however, does not make it possible to identify such an organism.

The authors of this paper have received some evidence, however, as to the identity of Howard's *Bacillus milii*. Howard sent bouillon and agar cultures of what he claimed was *Bacillus milii* to one of his correspondents stating that it was possible that the culture was not pure. Accompanying the cultures was a stained cover-glass preparation which he said was prepared from the vegetative form of the bacillus. The cultures, together with the stained preparation, were forwarded to us. In the cultures was found only *Bacillus alvei*. The stained preparation contained apparently only spores (not vegetative forms), and as far as it is possible to know from a microscopical examination these spores were the spores of *Bacillus alvei*. Such facts should dispel any particular anxiety one might possess concerning the existence of such an organism as *Bacillus milii*.

HARRISON, DECEMBER, 1900.

The next paper to be considered is one by Harrison.¹ In commenting upon the work of Cheshire and Cheyne, he asserts that these men established the causal relation of *Bacillus alvei* to foul brood by successfully applying Koch's rules in their work. He rehearsed in his paper the spraying experiment which Cheshire was supposed to have done and stated that since that time *Bacillus alvei* has generally been regarded as the cause of the disease.

In the beginning of his work, then, Harrison, like Mackenzie, accepted the work of Cheshire and Cheyne as conclusive that *Bacillus alvei* is the cause of foul brood. It is very unfortunate that these two men should have made this mistake, as their papers have had the effect of strengthening two erroneous ideas: First, that the two maladies which together were known as foul brood were one disease; and second, that *Bacillus alvei* is the cause of the disorder.

Harrison was aware of the fact that some bee keepers believed that there was more than one disease included under the name foul brood, since, in commenting on the work of Dickel and Klamann, he states that Dickel writes of one form of the disease which affects the unsealed brood, and of another form which affects the sealed, and even a third form, a mixed form which seems to be still more malignant. He states furthermore that Klamann suspected two kinds of disease.

Harrison entertained the following ideas concerning foul brood. The disease affects chiefly the larvæ, and when they are attacked they no longer lie curled up in the cell but are extended in it or move about unnaturally. The adult bees by a sort of inertness which seizes them may at this time show symptoms of the disease. The affected larvæ become flabby and die, and as a result of the decomposition which sets in, the decaying mass takes on a yellowish color. The yellow turns to a brown and when touched by a pin at this time or later, a portion of the mass may be pulled out in a long, ropy, tenacious string. This ropy mass dries down gradually to a brown scale which adheres to the wall of the cell. The bees as a rule are not active in removing larvæ dead of this disease from the cells, but, on the contrary, they are quite inactive, without desire to fly, but they may be seen fanning at the entrance of their hive. At this time a foul odor may be detected coming from the hive. The phase of the disease which some authors discuss as being a different form, Harrison states, is the same disease but that the larvæ die after being capped over instead of before. The capping of the cells containing such larvæ becomes indented or sunken and finally perforated. By

¹ Harrison, F. C., B. S. A., December, 1900. Foul brood of bees. Bulletin 112, Agricultural College and Experimental Farm. Pp. 32. Toronto. Portions of this bulletin are quoted in Bulletin No. 70, Bureau of Entomology, U. S. Department of Agriculture, pp. 23-26.

inserting a pin in either of these cells the same ropy mass may be drawn out. If an examination is made of the juices of the larvæ at different stages of the disease the bacilli may be seen. Spores form only after the death of the larvæ. The ropy decaying mass as well as the scales contain large numbers of these spores.

Weighing these facts it seems quite probable that Harrison was working with but one disease, American foul brood. In his examination of the ovaries of queens taken from foul-brood apiaries, Harrison reports the finding of bacilli in three queens. He reports that he found bacilli in a larger number of eggs laid in an affected colony, and writes:

In view of these facts, I am of the opinion that the eggs of bees from diseased hives may in some instances be infected.

Harrison did not find *Bacillus alvei* in any case of chilled brood which he had examined and states that Mackenzie performed several experiments with chilled brood and never found this organism in any case where the brood had not been inoculated experimentally. Harrison writes as follows concerning the distribution of the disease:

I have examined diseased larvæ from Canada, from Europe (France, Switzerland, Austria, Germany, Italy and England), Cuba, and 13 States of the Union, ranging from New York to California and from Michigan to Florida, and have succeeded in isolating *B. alvei* from all of them. It is true that some of the cultures show certain differences, but they have not been sufficiently pronounced to constitute even a well marked variety of the species.

Harrison may have isolated *Bacillus alvei* in limited numbers from material received from all these sources, but from his description of *Bacillus alvei* one can not be sure that he always identified his culture correctly.

It may be well at this point to consider Harrison's description of the organism which he identified as *Bacillus alvei*. In an abridged form it is as follows:

Occurrence.—Found in larvæ of bees suffering from a disease known as foul brood.

Gelatin plates.—The appearance of the growth depends upon the age of the colonies and character of the medium. In 24–36 hours at 22° C. the colonies are observed to be small, oval, or lozenge-shaped, bearing peculiar shoots extending frequently from one end and giving it a pear-shaped appearance. At the end of 48 hours the colonies are larger, with fine projections shooting out in all directions and forming circles. Later this appearance is destroyed by the liquefaction of the gelatin.

Agar plates.—In 12 hours at 37° C. the colonies are small and burr-like. Further, concerning the growth on agar, he writes:

On agar plates streaked with a light inoculation, most beautiful forms occur. The growth of the bacilli spreads over the surface and branches repeatedly, giving the

appearance of seaweed. This appearance is distinctively characteristic; and as the growth is very rapid, this method commends itself for making a quick diagnosis of the presence of the bacillus in larvæ supposed to be diseased.

Morphology.—A slender bacillus with slightly pointed but rounded ends. They usually occur singly, but may form chains of various lengths. This species possesses a single flagellum at a pole. No capsule has been demonstrated.

Spores.—The spores are about $2\ \mu$ in length and $1\ \mu$ in breadth. Under favorable conditions they begin to germinate in about three hours.

Motility.—They are actively motile, especially in fresh cultures.

Oxygen requirements.—Harrison agrees with Cheyne (p. 31).

Bouillon.—In 14 hours at 37° C. there is a slight cloudiness, in 24 hours the culture is turbid, and in 48 hours the turbidity is further increased and a pellicle begins to form. After 96 hours the broth is rather clear, with a white, rather massive, and somewhat tenacious pellicle. Reaction of the medium after 10 days has changed from $+0.08$ to the neutral point.

Glucose.—Growth heavier in this medium than in plain bouillon. Reaction in 10 days is acid, having changed from $+2$ to $+4.6$. Involution forms may occur. They are slightly curved and average $5\ \mu$ in length.

Lactose.—The growth resembles that in plain bouillon, but is slightly heavier. Acid is produced but less in quantity than in glucose.

Saccharose.—Turbidity is greater than in any other bouillon and more acid is produced.

Potato.—Harrison writes:

On potatoes the growth differs considerably, according to the reaction and age of the potato. Sometimes a brownish wrinkled growth forms, which gives off a peculiar odor; at other times a dryish yellow layer appears.

Milk.—At 37° C. coagulation of the casein occurs in three days. The medium becomes yellowish in color and gives off a peculiar odor. The coagulum finally digests, leaving a wheylike fluid.

Blood serum.—Growth takes place slowly. Many long filaments are common, which may be wavy and which may vary in thickness. The serum is liquefied.

Gelatin tubes.—On the surface in three days there occurs a ramifying growth. In five days the entire surface is liquefied. A whitish growth takes place along the line of puncture, from which numerous shoots branch out in the gelatin in all directions. This gives a haziness to the medium, which now begins to liquefy.

In the description which Harrison made he quotes rather freely from Cheyne. Some of his statements suggest that at least part of the time he was working with other species than *Bacillus alvei*.

One polar flagellum (p. 56) does not apply to *Bacillus alvei*. A heavy, tenacious pellicle does not suggest *Bacillus alvei*. The liquefaction in five days of the surface gelatin in tubes containing this medium does not suggest *Bacillus alvei*. The surface growth on agar, which Harrison describes as resembling "seaweed," is not encountered in the study of *Bacillus alvei*. These last three cultural characters are observed, however, in members of that group of bacteria of which *Bacillus A* (p. 76) is a member.

Harrison used cultures which he identified as *Bacillus alvei* in performing a number of laboratory experiments bearing directly upon the treatment of foul brood. His object was to determine the antiseptic value of various drugs for this species. The results obtained by this method of testing the antiseptic value were reported for weak solutions of salicylic acid, camphor, thymol, carbolic acid and tar, creolin, eucalyptus, beta naphthol, naphthalene, and formic acid. In doing this the drug to be tested was added to agar. The agar was inoculated with a pure culture of the organism, and observations were made as to whether a growth took place on this medicated medium.

Harrison gives the results of experiments in which he used two colonies of bees to test the value of naphthol and formic acid in the treatment of foul brood. The results which he obtained, however, can have only a relative value in treatment, since the organism with which he worked has most likely no etiological relation to any disease, or at least an unimportant one. Harrison had reached the conclusion that considerable attenuation in cultures of *B. alvei* may take place by its prolonged growth on artificial media. Since old cultures on this ground might be objectionable, he used, in his experimental inoculation, cultures which were only three generations from the diseased larvæ.

The further technique, in the carrying out of his experiment, involved the feeding of the spores from cultures to each of two healthy swarms placed side by side. The spores were scraped from the surface of an agar slant, put into 10 cc. of water, and well shaken. This suspension was then poured into medicated sirup. One colony was fed sirup containing the spores of *B. alvei* and one-third of a grain of beta naphthol to 1 liter of the sirup. The other colony was fed sirup containing the spores of *B. alvei* to which about 1.8 cc. of formic acid to a liter of sirup had been added. In both cases the medicated and inoculated sirup was taken up readily by the bees. The feedings were continued for three weeks, feeding four times per week. Each colony received in this way the growth from 12 agar slants. During the feeding period the combs containing the brood were examined, but no typical symptoms of the disease appeared. Cultures of *B. alvei* were obtained, however, from different parts of

the hive and from the digestive tract of the workers. After the third week, to each colony the feeding of ordinary unmedicated sirup containing the spores of *B. alvei* was practiced. In each experimental colony typical symptoms of the disease are reported to have been observed in 10 days, and a well-established disease after 16 days.

This experiment is offered as proof by Harrison that the feeding of an antiseptic in the treatment of foul brood is beneficial, as it hinders the germination of the spores of *B. alvei*. This confirms, he states, the opinion of Lortet that the digestive canal of the nurse bee is alone affected. Harrison reports the finding of *B. alvei* in the digestive canal of adult bees taken from diseased colonies.

After giving the results of his experiments, Harrison writes the following conclusion:

From the results of the above experiments I conclude that in certain cases the use of chemicals is beneficial, but I would not say that other measures, such as starvation and stamping out, should be abandoned as unnecessary or useless. Some of the drugs used are of very little, if any, value; but others, such as formic acid and naphthol B, are undoubtedly very useful. In some cases, especially those in which the disease is very virulent, it may be advisable to resort to more drastic measures.

In another experiment he reports that symptoms of the disease were produced after 14 days when *B. alvei* was fed. In these inoculation experiments, cultures were used which had been recently isolated in order that the virulence might not be diminished. He reports one experiment, however, in which cultures were used which had been transferred 30 times, with the result that several weeks elapsed before the disease appeared and then only in a light form.

One observes here that Harrison reports at least four cases in which foul brood developed after feeding the spores of *B. alvei* in sirup. These are of special interest inasmuch as many failures have been made since that time to obtain the symptoms of foul brood by similar inoculations. It would be well if Harrison could repeat these feeding experiments for confirmation.

The following summary contains some of the features of interest in Harrison's paper:

1. It has now been 11 years since the bulletin by Harrison, which is here briefly reviewed, was published, and very naturally, as its author no doubt will agree, it is in need of revision.

2. He has given in the historical résumé a brief account of the results and beliefs of a number of workers and writers on foul brood.

3. He believed that the two forms of foul brood described by some authors were only two phases of the same disease, one form being that phase of the disease in which the larvæ die just before capping, and the other one that phase of the same disease in which the brood dies after capping.

4. He gives a geographical distribution of foul brood, having determined it by the isolation of *B. alvei* from diseased larvæ.

5. He reports the finding of *Bacillus alvei* in the ovaries of queens, and concludes that the eggs in diseased hives might sometimes be affected.

6. He has given quite a lengthy description of *B. alvei*.

7. He was not able to isolate *B. alvei* from chilled brood as the condition is found in the apiary.

8. He performed various experiments to prove the value of drugs in the treatment of foul brood, with the conclusion that drugs in certain cases—for example, formic acid and beta-naphthol—are undoubtedly very useful, while some others are of very little or no value.

9. He also reports the successful production of the disease with typical symptoms by feeding the spores from pure cultures of *B. alvei*.

10. He mentions no difficulty in obtaining *B. alvei* from "foul-brood" material.

The authors of this bulletin disagree with nearly all of the points made by Harrison. His failure to recognize the fact that the mass of spores, which are always seen in brood dead of American foul brood, do not grow when plate cultures are made, was fatal to his work. Occasionally colonies of *Bacillus alvei* do appear on plates, made from this disease, but when they do they appear only in relatively small numbers.

LAMBOTTE, SEPTEMBER 25, 1902.

A paper by Lambotte¹ caused, at the time it was written, considerable discussion among bee keepers. It caused some comment also on the part of others on account of the views which he expressed concerning the identity of *Bacillus mesentericus vulgaris* and *Bacillus alvei*, and the relation of *Bacillus mesentericus vulgaris* to foul brood.

In view of the fact that foul brood seemed to appear unexpectedly away from all known sources of infection, a beekeeping society petitioned the minister of agriculture of Belgium to have a new scientific study of foul brood made. Lambotte's work is the result of this petition. From requests made through journals, an ample supply of foul-brood samples was received. The diseased larvæ in capped cells were recognized by the darkened, sunken, and usually perforated cappings. The brood dead of the disease he describes as being yellow or brownish-yellow, viscid, ropy, and emitting a nauseating odor.

From a stained preparation made from ropy larvæ, Lambotte observed a very large number of spores which he supposed were the

¹ Lambotte, Dr. Ul., September 25, 1902. Recherches sur le microbe de la "loque," maladie des abeilles. Travail du laboratoire de l'institut de pathologie et de bacteriologie de l'université de Liège. Annales de l'Institut Pasteur, Tome XVI, No. 9, pp. 694-704.

spores of *Bacillus alvei*. When he inoculated gelatin, agar, or bouillon with some of this ropy larval mass, no growth took place and when he used larvæ which were more recently attacked, the same failure to obtain a growth was observed. He took these facts to mean that there is something present in the foul-brood larvæ which prevents, by its antiseptic property, the growth of the bacteria. He proceeded, therefore, to inoculate a considerable quantity of sterile bouillon, in order that the supposed antiseptic present might be diluted, thus permitting the germination of the spores. By following this technique a growth was obtained and he interpreted it to be the growth of the spores which he had observed microscopically in such large numbers in the diseased brood.

The bacillus which he thus obtained he isolated in a similar manner from a large number of samples of "foul brood," and by a study of its morphology and cultural characters Lambotte identified it as being the one described by Cheyne as *Bacillus alvei*. Furthermore, he studied the morphology and cultural characters of a number of cultures of *Bacillus mesentericus*, and by a comparison of these with those of *Bacillus alvei* he reached the conclusion that the two are very similar.

To show more conclusively that *Bacillus alvei* and *Bacillus mesentericus* are very similar, Lambotte made use of the phenomenon of agglutination. Guinea pigs were used in his experiments. In immunizing the animals he used a suspension of an agar culture of *Bacillus alvei* and *Bacillus mesentericus*, respectively, in physiological salt solution. In each case the animal received four inoculations at weekly intervals. He reports that the serum of an untreated guinea pig did not exhibit, upon examination, the phenomenon of agglutination. The serum of a guinea pig, on the other hand, which had been treated by inoculations with *Bacillus alvei*, agglutinated a culture of this species at a dilution of 1 to 350, and the serum from the same animal agglutinated cultures of *Bacillus mesentericus* at a dilution of 1 to 250. Furthermore, the serum of a guinea pig that received the inoculation of *Bacillus mesentericus* agglutinated *Bacillus mesentericus* as well as *Bacillus alvei* at a dilution of 1 to 250. Neither of these two sera agglutinated any other bacilli at these dilutions. This caused Lambotte to conclude that *Bacillus alvei* and *Bacillus mesentericus vulgaris* are the same species.

Having convinced himself that this very intimate relation exists between *Bacillus alvei* and *Bacillus mesentericus vulgaris*, he attempted to prove by the inoculation of healthy colonies that foul brood could be produced with cultures of *Bacillus mesentericus*. He killed some of the larvæ by pricking them and placing a suspension of *Bacillus mesentericus* in the cell with the dead larvæ. He hoped

that foul brood might be started in the colony, but repeated attempts resulted each time in failure.

He then made a medium from bee larvæ by the use of which he thought he had obtained by successive inoculation a special variety of *Bacillus mesentericus*. He supposed that if *Bacillus mesentericus* were grown upon the bee-larvæ medium its virulence for bees would be increased. After using the culture of *Bacillus mesentericus*, which had been grown upon the bee-larvæ medium, and after inoculating larvæ as before, he reports that foul brood was produced with the typical symptoms of the disease. The only exception noted was that fewer cells were affected.

He attributed his good results to two facts, first, that *Bacillus mesentericus* was cultivated on a bee-larvæ medium, and second, that the experimental inoculation was made at a time of the year when the activity of the hive was considerably diminished. To the latter factor he attributes most of his success. He states that a colony inoculated with *Bacillus alvei* or with *Bacillus mesentericus* grown on a bee-larvæ medium will not allow itself to become infected when it is active at the beginning of the season.

In his conclusions Lambotte writes:

(1) *Bacillus alvei*, described by Watson Cheyne and Cheshire as the specific cause of foul brood, is simply the widely distributed organism *Bacillus mesentericus vulgaris*.

(2) *Bacillus mesentericus* can be found in healthy hives, in the cells of the comb, and in the intestines of bees.

(3) *Bacillus mesentericus*, by growth in the tissues of larvæ, produces changes characteristic of foul brood.

Lambotte insists that the hygiene of the colony is above all the most important in the control of foul brood. He believes that unless the resistance of the larvæ to infection is maintained by good hygiene, *Bacillus mesentericus*, which is so widely distributed in nature, may invade the colony and produce foul brood in any apiary.

A brief summary of Lambotte's works may be made as follows:

1. He did not take into consideration the two forms of foul brood described by some authors, working for the most part, at least, with American foul brood only.

2. He observed that in American foul brood it was not easy to obtain a growth of the spores which are found in such large numbers on microscopic examination.

3. He suspected that an antiseptic was present in the dead remains of the larvæ in this disease which prevented the growth of the spores. The effect of such an antiseptic he hoped to overcome by diluting it with a large amount of the medium used for its cultivation.

4. He obtained a bacillus by this special technique and identified it as the *Bacillus alvei* of Cheyne and Cheshire.

5. He compared *Bacillus alvei* and *Bacillus mesentericus vulgaris* and arrived at the conclusion that they are one species and offered as proof of it that the morphology and cultural characters of the two are similar, and that the serum of an animal immunized with *Bacillus alvei* will agglutinate *Bacillus mesentericus vulgaris* and vice versa. Furthermore, he claimed that foul brood can be produced with cultures of *Bacillus mesentericus vulgaris*.

6. He believed that when the resistance of the larvæ is for any reason lowered *Bacillus mesentericus*, if introduced, can become virulent and produce "foul brood." In this way he explained the presence of "foul brood" in an apiary without the introduction of infective virus from without.

This work of Lambotte has been criticised by different writers since its appearance. The spores which he observed to be difficult of germination were most likely not caused to germinate by the technique which he used. It would seem also that he was in error in concluding that *Bacillus mesentericus* and *Bacillus alvei* are one species. This conclusion led him to the unlikely supposition that "foul brood" might appear in any apiary without the introduction of an infective virus other than the widely distributed and commonly met with organism *Bacillus mesentericus vulgaris*.

HARRISON, FEBRUARY 28, 1903.

In a review, Harrison¹ disagrees with some of the views expressed in Lambotte's paper (p. 53). He did not believe with Lambotte that *B. alvei* and *B. mesentericus vulgaris* are one species. It was his opinion that Lambotte's work on these two species was insufficient to establish their identity. Harrison compared the descriptions of the two species made by different authors and offered the results as evidence that the two were different. In offering the evidence he states that he did not have time himself to make, for comparison, a study of the cultures themselves. Harrison was led to believe that Lambotte began his experiments with *Bacillus mesentericus vulgaris* and not with *Bacillus alvei*.

Two minor points of considerable interest are also recorded: First, Harrison at this time states that he too had had at times some difficulty in obtaining a growth from the spores in "foul brood"; and second, he now credits Cowan for having said that *Bacillus alvei* possessed but one flagellum.

The following sentence from Harrison's paper is offered as an argument to disprove the identity of *Bacillus alvei* and *Bacillus mesentericus vulgaris*:

¹ Harrison, F. C., February 28, 1903. *Bacillus mesentericus* et *B. alvei*. Revue Internationale d'Apiculture Tome XXV, No. 2, pp. 29-32.

If Dr. Lambotte's theory that *Bacillus mesentericus vulgatus* and *Bacillus alvei* are identical is true, we should naturally expect to find cases of foul brood arising spontaneously in countries which never import bees or material from infected localities.

This assertion could be admitted as evidence if *Bacillus alvei* were known to have as important an etiological relation to foul brood as Harrison supposed that it had (p. 48). One of the facts which prompted Lambotte's investigation was that the disease seemed to break out independently of any source of infection. If any casual relation does exist between *Bacillus alvei* and any form of foul brood, and if his theory concerning the identity of *Bacillus alvei* and *Bacillus mesentericus vulgaris* can be established, Lambotte offered a very clever explanation for the existence of the apparently sporadic cases of the disease.

It is not likely that Lambotte produced foul brood with either *Bacillus alvei* or *Bacillus mesentericus vulgaris*. The two species are most likely different species, but the evidence advanced by Harrison to prove that the two are different is inferior to that which Lambotte produced to establish their identity. Lambotte made his greatest error apparently in faulty observations.

In the opinion of the writers, both Harrison and Lambotte were probably describing their experiences with American foul brood, and the spores which they saw in such large numbers were those of *Bacillus larvæ*. The growth which they obtained was not a growth from these spores, but a growth of *Bacillus alvei* or a member of the group to which *Bacillus mesentericus vulgaris* (*Bacillus A*, p. 76) belongs. Either of these species may be present but occur most always in small numbers.

Another point of considerable interest might be mentioned here. In a paper by Harrison¹ presented to the Bee Keepers' Association of the Province of Ontario in November, 1904, the following is found:

Two years ago I remember there was some talk of black brood, and I think a committee was appointed to send samples to me. Whether they did not meet with any cases of black brood or no I don't know, but I know I have received no samples, * * *.

This statement tends to confirm the suspicion already expressed that Harrison was working with American foul brood.

In an address² delivered in November, 1905, before the Bee Keepers' Association of the Province of Ontario, Harrison announced to the association that he was leaving his position as director of the association and representative of the agricultural college. Since that time we have not learned of any work on bee diseases published by

¹ Harrison, F. C., 1905. Diseases of bee larvæ. Annual Report of the Bee Keepers' Association of the Province of Ontario, 1904. Toronto, pp. 27-36.

² Harrison, F. C., 1906. Diffusing apicultural knowledge. Annual Report of the Bee Keepers' Association of the Province of Ontario, 1905, pp. 8-10. Toronto.

him. It is to be regretted if the duties in his new position limit his activity in this line of research.

MOORE AND WHITE, JANUARY 15, 1903.

In the spring of 1902 Moore, assisted by one of the writers of this bulletin, began the investigation of the bee diseases that were present in the State of New York. Neither was familiar with the manifestations of the different diseases attacking bees, further than the information which could be obtained from the publications of Cheshire and Cheyne, Howard, Harrison, and data obtained directly from the four inspectors of apiaries of that State—Messrs. West, Stevens, Stewart, and Wright. The samples of brood examined were received from these inspectors with the diagnosis of each sample already made. The first report ¹ which was made to the commissioner of agriculture of that State on the investigation gives a brief account of the examination of 10 samples labeled “black brood,” 7 samples labeled “foul brood,” and 5 samples labeled “pickled brood.”

William R. Howard, it will be remembered (p. 44), received samples of diseased brood from N. D. West, of New York. He examined them and reported the disease as new, naming it “New York State bee disease” or “black brood.” He ascribed the cause of the disease to a bacillus, to which he gave the name *Bacillus milii*. The 10 samples labeled “black brood,” and examined by the authors of the paper under consideration, were all from New York State and 7 of them were diagnosed by Mr. West.

The bacterial findings recorded by Moore and White show that *Bacillus alvei* was present in all the samples, while there is no record of *Bacillus milii* in any of them. Other bacteria, which appeared in most instances to be micrococci, were occasionally associated with *Bacillus alvei*. The absence of any bacillus corresponding to the description of *Bacillus milii* in these samples of so-called “black brood” was strong evidence that such a species was not the cause of the disorder.

The question naturally arose as to whether this trouble was a new disease, as Howard had led the people to believe. In forming an opinion as to whether a new disease existed, the work of Howard and others was considered. Cheshire and Cheyne (p. 25) had described the symptoms of “foul brood” and had apparently found *Bacillus alvei* present in sufficient numbers to suspect this species as the cause of the disease. Harrison (p. 48) had found a species in “foul brood” which he had identified as *Bacillus alvei*. Lambotte (p. 53) had done

¹ Moore, Veranus A., M. D., and G. Franklin White, B. S., January 15, 1903. A preliminary investigation into the cause of the infectious bee disease prevailing in the State of New York. State of New York, Department of Agriculture, Tenth Annual Report of the Commissioner of Agriculture, for the year 1902, pp. 255-260, two plates.

likewise. Ten samples of diseased brood were therefore examined which corresponded in gross appearance to the symptoms of the disease which Cheshire and Cheyne reported, and the bacteriological examination of these 10 samples revealed the presence of *Bacillus alvei* in numbers sufficient to lead one to suspect a causal relation of the organism to the disease. The conclusion that would be drawn from these facts regarding the disease, in the absence of Howard's work, very naturally would be that it is not a new disease, but simply "foul brood."

It was necessary now to weigh the evidence which Howard produced in support of the view that the disease was new. Howard received 5 samples from Mr. West and reported the presence of "*Bacillus milii*" in all of them, "*Bacillus thoracis*" in 2, and "*Aspergillus pollini*" in 1, but nothing was found in the samples of so-called "black brood" received and examined by Moore and White which could be identified as either species. The experimental data which Howard offered in support of his view was also very unsatisfactory.

In view of all these facts the authors of the report under consideration drew the conclusion: "That the prevailing disease [so-called black brood] in this State [New York] is very similar to, if not identical with, the 'foul brood' of other States, Canada, and Europe." This conclusion means that the disease, which the people of New York State were taught by Howard to be a new disease and which he chose to call "The New York bee disease" or "black brood," is not a new one, but is the one which Cheshire and Cheyne agreed was "foul brood."

Various inoculation experiments were now tried for the purpose of demonstrating whether or not *Bacillus alvei* is the cause of a brood disease. Several methods of inoculation which had been used by others in attempting to produce the disease in healthy brood experimentally were employed, but always with negative results. The most logical way to make the inoculation and the one which might be expected to give the most accurate results, very naturally, is by feeding the bees. This was tried with the hope that it would give the most accurate results.

The inoculation of one colony only is reported. A colony free from disease was fed, on August 4, sugar sirup, to which was added the spores of *Bacillus alvei* taken from agar plates and the vegetative form of the same species taken from fresh bouillon cultures. Similar feedings were given to the bees three times per week until September 28, but the symptoms of "black brood" did not appear. The results of this experiment, therefore, were negative, as were all the others as far as the producing of the disease was concerned. To make sure that some of the culture fed had reached the larvæ, cul-

tures were made from the larvæ before feeding and after feeding. *Bacillus alvei* did not appear on the plates made before the colony had been fed the culture, while many appeared on those made after the cultures were fed. The culture therefore reached the larvæ and no disease resulted. While the negative results of these few experiments were not sufficient to disprove an etiological relation between *Bacillus alvei* and foul brood, it did cause those doing the work to question the experimental results which others had reported.

The samples of American foul brood which were received and examined were labeled "foul brood." Six of the seven samples of this disease received gave no growth when cultures were made. Concerning the bacteriological findings in this disease the following is written:

Stained cover glass preparations made from the dried dead larvæ contained large numbers of spores, but they failed to grow in any of our media.

Since the spores which were found in such large numbers in the larvæ dead of this disease would not grow, no inoculation of healthy brood was attempted. The samples of this disease did not show, on examination, the presence of *Bacillus alvei*. This at once suggested the fact that the disease is not the one studied by Cheyne as foul brood.

A study of five samples of the so-called pickled brood gave practically negative results both microscopically and culturally. The point to be noted here is that no fungus was found in this disorder corresponding to the one described by Howard (p. 42) as *Aspergillus pollini*. This fact very naturally suggested the probability that Howard had made another error in the determination of the cause of a brood disease.

The report included the study of brood from only three healthy apiaries. In samples taken from two of them, *Bacillus alvei* was not found, while a sample from the third apiary which was thought to be healthy but in a diseased district, showed the presence of *Bacillus alvei* in considerable numbers.

The following facts were learned in the investigations just reviewed:

1. At least two infectious diseases affecting the brood of bees exist. This fact had been known, however, for some time by the inspectors of apiaries of New York State, and by Dzierzon (p. 18) and many others years before.

2. Howard had erroneously reported European foul brood to be a new disease, which he named the "New York bee disease" or "black brood."

3. To produce foul brood in a healthy colony by feeding cultures of *Bacillus alvei* was by no means easy.

4. The results reported by others regarding the causal relation between *Bacillus alvei* and "foul brood" were questionable.

5. The spores found in the brood dead of American foul brood would not grow on the media commonly used in the laboratory, suggesting the possibility of a new and interesting species.

6. The disease which was being diagnosed as "foul brood" is not the foul brood studied by Cheyne, but is another disease now known as American foul brood.

7. *Aspergillus pollini* was not present in the samples labeled "pickled brood," meaning that the condition was not Howard's "pickled brood," or that he had made another error in his study of the condition.

8. No colonies of *Bacillus alvei* appeared on the plates made from the brood of two healthy apiaries, but colonies of that species did appear in considerable numbers on plates made from brood taken from a third apiary which was considered healthy, but located in an infected district.

9. Lastly, much work would have to be done on bee diseases before the confusion could be cleared up and the causes demonstrated.

WHITE, JANUARY 15, 1904.

In 1904 another paper¹ appeared giving the results of some investigations on bee diseases made during the summer of 1903. The work was a continuation of that done the preceding year.

It was desirable to know whether *Bacillus alvei* was constantly present in the samples of the so-called black brood. If this species could be found in large numbers in every sample of this disease and not in other conditions, it would be a valuable means of diagnosing the disease as well as suggesting a possible etiological relation between the organism and the disease.

Toward establishing the constant presence of *Bacillus alvei* in the foul brood of Cheshire and Cheyne (the so-called black brood) 26 samples were examined and *Bacillus alvei* was found in all of them. Twenty-four of the 26 samples were sent by Mr. West, but no species was found in any of them which was suspected as being *Bacillus milii*. These bacteriological findings, therefore, corroborated the conclusion of the preceding year that the so-called black brood is simply the foul brood of Cheshire and Cheyne.

Inasmuch as the efforts to produce foul brood with cultures of *Bacillus alvei* failed to give positive results in 1902 (p. 59), further attempts were made to determine the pathogenesis of this species for

¹ White, G. F., January 15, 1904. The further investigation of the disease affecting the apiaries in the State of New York. State of New York, Department of Agriculture, Eleventh Annual Report of the Commissioner of Agriculture, for the year 1903, pp. 103-114.

bees. In the feeding experiments of this year some of the brood died. This slight difference in the results, from those obtained the preceding year, was probably due to the difference in the details of the experiment. Although some of the brood was found dead, the condition did not present sufficient symptoms, in the opinion of the author, to justify him in pronouncing it foul brood. Many punctured cappings were observed and dead larvæ of a dull color were present. These dead larvæ were found by cultures to contain *Bacillus alvei*. The death of these larvæ might have resulted from chilling or other causes, and the cappings may be punctured by the bees in different conditions that result in the death of the brood after capping.

The presence of *Bacillus alvei* could easily be explained from the fact that cultures can be isolated from apparently healthy larvæ taken from a colony to which the spores of the species has been fed. There was also wanting in these dead larvæ the yellowish color usually observed in those affected with European foul brood. The slightly viscid character which is sometimes present in brood dead of European foul brood was also absent. The rapidity with which the condition disappeared when the days became warmer was another indication that the disease was not European foul brood. The results of the experimental inoculation of healthy brood with cultures of *Bacillus alvei* were negative, and were therefore similar in this respect to those of the preceding year.

Since a number of articles had appeared about that time advocating the use of formaldehyde gas in foul-brood treatment, some preliminary experiments were conducted to test the efficiency of this disinfectant when applied to brood combs. The experiments demonstrated that it is not easy to destroy the spores which are within the dead larvæ and that the gas as it was being applied in the treatment of the brood diseases could not be relied upon.

The samples of American foul brood which were received for examination in 1902 were labeled "foul brood" when received. From the time Cheshire and Cheyne published their joint paper in 1885 to 1902 *Bacillus alvei* was suspected as being the cause of "foul brood." *Bacillus alvei*, however, was not encountered in the samples labeled "foul brood" received and studied in 1902 (p. 60). Spores were found present in the decaying remains of the dead brood, but they refused to germinate on artificial media.

The first time that these spores were caused to germinate under laboratory conditions was in 1903. For this purpose a special agar medium was used, made from the larvæ of bees. A somewhat similar medium had been used by Lambotte (p. 55), but with it he did not obtain a germination of these spores. This special agar was used in a test tube, and Liborius's method for making inoculations was

employed. Until the organism could be further described, and until there was more evidence that there was a causal relation existing between the species and the disease with which it was found associated, it seemed best to refer to the bacterium as *Bacterium* "X" and to the disease as "X brood." Seven samples of this disease were studied in 1903, and *Bacterium* "X" was found by cultures in all of them.

The disease called "pickled brood" received some further study at this time. The most striking feature in the results was the record of no growth from the cultures. The following is taken from the report:

The results of the examinations showed that "*Aspergillus pollinis*" was not found. Further investigations must be made before any conclusion can be drawn as to the real cause of this trouble.

Concerning paralysis in adult bees, the following was written:

The disease known to the apiarists as palsy or paralysis attacks the adult bee. The name is suggestive of the symptoms manifested by the diseased bee. A number of bees affected were received from Messrs. Wright and Stewart taken from apiaries in New York State. Bacteriological examinations have been made of a number of the bees so affected but no conclusions can be drawn from the results thus far obtained as to the cause of this disorder.

The following is a brief summary of the results obtained during the year 1903:

1. *Bacillus alvei* was found in all samples of European foul brood examined.

2. A causal relation between *Bacillus alvei* and European foul brood seemed questionable.

3. *Bacillus alvei* was not encountered in any sample of American foul brood.

4. The samples of American foul brood did contain, however, a species which was referred to as *Bacterium* "X," in such numbers and with such constancy as to suggest an etiological relation to the disease.

5. A growth of this species was obtained on artificial media.

6. Neither "black brood" nor "*Bacillus milii*" was found. The work of the year seemed to confirm the idea that the so-called "black brood" was simply the foul brood of Cheshire and Cheyne.

7. The cultural results obtained from the so-called pickled brood were practically negative.

8. The "*Aspergillus pollini*" named by Howard was not found in any disorder of the brood of bees.

9. A disease called palsy or paralysis by the bee keepers seemed to be a malady, but no cause was found.

10. Formaldehyde gas as ordinarily used in the apiary would not insure complete disinfection.

BAHR, 1904.

A paper on the diseases of bees by Dr. L. Bahr,¹ of Denmark, bears the date 1904. The author gives a brief review of the work on bee diseases, together with some interesting observations by himself. In that portion of his paper describing his own observations the following is recorded:

A number of samples of brood have been sent to me from various parts of the country (Denmark) having the following symptoms: Some of the diseased larvæ were quite small, while some of them are older—from 4 to 6 days. They never become ropy as those of foul brood, but retain their form until they approach the consistency of gruel. The color is whitish yellow but sometimes somewhat darker. In the gruel-like mass of the diseased larvæ I found a very small oval bacterium.

Bahr mentions that the disease seems to be quite contagious. From his description of the disease and from his bacteriological findings there is a strong suggestion that the disease to which he refers is European foul brood. Sufficient facts, however, are not given to make this point at all positive. The author states that his studies were not completed.

BURRI, OCTOBER AND NOVEMBER, 1904.

We shall now consider a very excellent piece of work on foul brood by Dr. Burri.² In his introductory remarks this author very aptly refers to the need and value of a scientific study of foul brood.

Burri began his work on foul brood apparently in the spring of 1903. He observed that the foul odor which is emphasized so much in the literature on "foul brood" is not constant for all samples. Studying the different samples he concluded that the ropiness of the decaying larvæ and the tonguelike scales on the lower side wall of the cell were characteristic of typical "foul brood."

He also calls attention to the very large number of spores in the decayed foul-brood larvæ, and the absence of any vegetative forms. Cultures were made from these dead larval remains, but there was no germination of the numerous spores. The occasional colony which did appear he attributed to an accidental contamination with a different species. Failing in his attempt to obtain a growth of these numerous spores, Burri came to the conclusion that they were a new species that would not grow on the media ordinarily used in the laboratory. He added to his medium some cooked healthy larvæ somewhat similar to the medium used by Lambotte, but with this special medium he did not obtain the growth desired. Failing still to obtain a growth of the species, he proceeded with the study of its morphology as observed in the various stages of decay of the brood.

¹ Bahr, L., 1904. Vore Bisygdomme. Foredrag holdt ved DBF's diskussionsmøde i Grejsdalen den 11 Septbr. 1904. Særtryk af Tidsskrift for Blavl Nr. 16 og 17.

² Burri, Dr. R., October and November, 1904. Bakteriologische Forschungen über die Faulbrut. Schweizerische Bienenzeitung, Nro. 10, pp. 335-342; Nro. 11, pp. 360-365.

Further attempts were then made to study the species culturally. He smeared some freshly infected larvæ supposed to contain only rods upon a certain medium and obtained spore-bearing rods and spores similar to those which had been observed in the diseased larvæ. He made a similar inoculation from the dead larvæ which had turned brown and which contained only spores, and as a result of this inoculation he obtained motile rods which later formed spores. Burri was somewhat inclined to believe that pure cultures had been obtained by his method of inoculation, although he states that the obtaining of pure cultures of this organism had to remain an unfulfilled wish.

From his studies Burri came to the conclusion that the organism is neither *Bacillus alvei* nor *Bacillus mesentericus*, but a new one. He repeated some of the experiments reported by Lambotte (p. 53), but was inclined to believe that the latter was in error. Besides studying from a number of samples this form of foul brood to which he referred as the nonstinking form (most probably American foul brood), Burri received and studied other samples of foul brood to which he referred as the foul-smelling form (most probably European foul brood). In the latter disease he found a large number of bacteria unlike those observed in samples of the other disease studied. The species which was present in large numbers in the latter samples grew without difficulty when sown on artificial media, and he identified it as *Bacillus alvei* Cheshire and Cheyne (p. 25).

We are not inclined to think of this latter disease (European foul brood) as the one which is the more foul smelling of the two, nor the former the ropy form (American foul brood) as the less stinking one of the two. It is true that only a few of the samples of American foul brood have a disagreeable odor when they reach the laboratory; nevertheless, the most disagreeable odor encountered in diseased brood when it is examined in the apiary is present in those colonies that are affected with American foul brood. It is American foul brood that the American bee keepers think of when they refer to the foul-smelling foul brood.

Burri encountered other bacteria than *Bacillus alvei* and the one which was difficult of cultivation. He mentions the presence of bacteria which he associated with a condition referred to as sour brood. He reports that he had always found foul brood present with this latter condition.

The following are the conclusions drawn by Burri in his paper:

1. There are in Switzerland, and also in other places, at least two distinct kinds of bacteria which can produce a typical contagious foul brood. In one case it is *Bacillus alvei* described by Cheshire and Cheyne; in the other a species of bacterium not formerly known, which is difficult to cultivate.

2. The two kinds of foul brood are easily distinguished from each other in the dried remains of the larvæ. That form of the disease in which *Bacillus alvei* is found exhibits an offensively smelling residue in which microscopically are found rods 2 μ in length, together with numerous spores. The larval remains in which are found the organism that is difficult to cultivate are almost odorless, and on microscopic examination spores 15 μ in length are recognized, but no rods.

3. Occasionally other bacteria which stand in a certain relationship to the so-called foul-brood germs obtain local significance as the cause of foul brood. Lambotte's view, on the other hand, that the potato bacillus (*B. mesentericus vulgatus*) is to be considered the cause of foul brood is yet without demonstration.

4. In choosing the methods for eradication of the disease, the fact that there are at least two kinds of foul-brood bacteria must be taken into consideration.

5. In every case a certain amount of knowledge of the bacteria in question is desired, not only from the scientific but from the practical point of view as well.

Some of the interesting facts noted in Burri's paper might be summarized as follows:

1. He recognizes two forms of foul brood.

2. He refers to the ropy type of foul brood (American foul brood) as the non-smelling form of the disease, and to European foul brood as the foul-smelling form.

3. He did not obtain a growth of the spores present in American foul brood either on the media ordinarily used in the laboratory or on a special medium to which cooked bee larvæ were added.

4. He studied the morphology of the organisms present in the foul-brood larvæ in a manner similar to that followed by Cheshire (p. 19).

5. He expressed doubt concerning the accuracy of the results reported by Lambotte.

6. In one disease (probably European foul brood) he obtained *Bacillus alvei* in very large numbers.

7. He found a condition to which he referred as sour brood, and with it he found associated a species to which he referred as sour-brood bacteria.

8. In his investigations he says foul brood always accompanied sour brood.

WHITE, JANUARY 14, 1905.

The work on bee diseases was continued during the year 1904 in New York State and was followed by another report.¹ The work of the year was devoted to the diagnosis of the brood diseases in the laboratory; to a study of "foul brood" (European foul brood) and "X" brood (American foul brood); and to a study of palsy or paralysis in bees.

The similarity that exists between samples of the different brood diseases was observed to be so marked at times that a diagnosis of a condition often could not be positively made without a bacterio-

¹ White, G. Franklin, January 14, 1905. State of New York, Department of Agriculture, Twelfth Annual Report of the Commissioner of Agriculture, for the year 1904, pp. 106-107.

logical examination. This called for considerable work in diagnosis in the laboratory. The results of the examinations showed that European foul brood and American foul brood were the diseases of bees which attracted most interest in the State.

Bacillus alvei was found to possess a number of flagella arranged peritrichic instead of one flagellum at a pole, as Harrison at first reported, but later accredited Cowan with the statement (p. 56). The fact that *Bacillus alvei* was supplied by more than one flagellum had already been pointed out by Lambotte.

Concerning *Bacillus* "X" (*Bacillus larvæ*) the following is found:

It is a slender rod with moderate motility having a tendency to form in chains. The formation of spores and the arrangement of flagella is somewhat similar to that found in *B. alvei*. While *B. alvei* grows quite well on all the artificial media commonly used in the laboratory, the growth of *Bacillus* "X" is not so easily obtained. The medium which is most successful in the cultivation of this species is the one made from the larvæ of bees. Growth has been obtained with difficulty upon ordinary agar and gelatin.

The so-called palsy or paralysis received some attention, but after beginning this work it was soon realized that before it could be done satisfactorily it would be necessary to know something of the normal bacterial flora of the healthy bee. A brief study of the bacterial species most frequently found within and upon the normal bee was therefore made.

WHITE, JUNE, 1905.

About the time that this last report was published, a manuscript embodying all of the work done on bee diseases at the New York State Veterinary College for the State of New York was prepared as a thesis.¹ Since the manuscript is available to but few, it will not be reviewed here. With very few changes this manuscript was published as Technical Series No. 14, Bureau of Entomology, United States Department of Agriculture (p. 76).

WILSON, 1905.

Of course it is very frequently impossible on account of inadequate descriptions to identify certain organisms. In the case of *Bacillus alvei* there is but little excuse for any mistake, since the description which Cheyne has made is entirely adequate for this purpose. In this connection a paper by Wilson² is of interest.

He used a culture for demonstration purposes in a medical school, which he isolated from the tonsils of a patient with suspected diphtheria and identified it as *B. alvei*. He claims that *B. alvei* is fre-

¹ White, G. Franklin. June, 1905. The bacterial flora of the apiary with special reference to bee diseases. Thesis, Cornell University, Ithaca, N. Y.

² Wilson, Dr. R. J., 1905. Morphological characteristics of the *Bacillus alvei*. Proceedings of the New York Pathological Society, vol. 5, pp. 79-81.

quently seen in cultures from the throat. Now, it may be that Wilson made a correct identification, but inasmuch as the source of the culture was the throat, he should have been very careful about making the identification positive.

It might be mentioned here that not a few bee keepers have been startled by an announcement that *B. alvei* is found in human sputa. Some of them have reasoned, very naturally, that if all reports were true the sputum might be the source of foul-brood infection, but there is no convincing evidence, of course, that such is the case.

BURRI, JANUARY, 1906.

Burri's next paper¹ was on "foul brood" and "sour brood." His discussion of foul brood is quite similar to that which appeared in his former paper (p. 64). We shall therefore direct attention at this time to that portion devoted to "sour brood."

The origin of the name "sour brood" is indefinite. Quoting from C. P. Dadant, an American writer, Burri writes that there are three diseases of the brood recognized in America—foul brood, sour brood, and black brood. This view would make sour brood synonymous with pickled brood, but as it will be learned later in his work on sour brood, Burri was studying for the most part at least European foul brood.

In his work Burri did not find a uniformity in the diseased brood examined either in the gross or the microscopic appearance. In one sample he found no bacteria, although the outward appearance of the larvæ indicated disease. In another sample the gross appearance did not suggest foul brood, and there were absent the bacteria which are commonly found in the disease; and in their stead there were present millions of bacteria which to the investigator did not seem to stand in etiological relation to the disease. In still a third instance the larvæ gave no outward sign of being killed by the bacteria of foul brood, but when studied culturally, they showed the presence of a very large number of unidentified bacteria together with a few of those which frequently accompany "foul brood." These findings illustrate, he says, some of the difficulties which are encountered in a study of the brood diseases bacteriologically.

Putting aside all samples which were unquestionably "foul brood," he attempted to group the remaining ones according to certain characteristics observed in a study of the gross appearance of the diseased brood. One character which seemed to be emphasized was the sour odor emitted by certain samples. On account of this he classified this condition as "sour brood." In testing the odor of brood dead of the disease, Burri recommends the holding of the nose

¹ Burri, Dr. R., January, 1906. Bakteriologische Untersuchungen über die faulbrut und Sauerbrut der Bienen. Pp. 39, pl. 1. Vorwort by U. Kramer.

very near the combs, or, better, the removal of a larva and testing it. He calls attention to the fact that "foul brood" (American foul brood) and "sour brood" (European foul brood) have probably often been confused by bee keepers of little experience and placed under one name, "foul brood."

Another point of difference between "foul brood" and "sour brood," as pointed out by Burri, is in relation to the consistency of the dead larvæ in the two conditions. In "foul brood," he says, a uniform ropy mass is all that remains of the decaying larva dead of the disease, while in "sour brood" the chitinous covering of the decaying larva permits its removal as a whole from the cell.

Besides the odor and consistency of the dead brood, Burri refers to the color as a third characteristic that serves to aid in the differentiation of "foul brood" and "sour brood." He writes that the larvæ of "foul brood" are cream colored soon after the development of the bacteria has begun, but later are a pale coffee brown, and finally a dark brown. In "sour brood," he says, the larvæ become discolored. At first they are a dirty yellow. The dry scales are less black than those of "foul brood."

Burri received samples which were reported to him to be "black brood." The older larvæ seemed to be affected and the microscopic and cultural examinations gave negative results. This strongly suggests that this is not the condition to which the term "black brood" has been referred in America. No conclusion was reached by him as to the cause of this trouble. Certain differences were noted by Burri between the descriptions by Dadant of the different brood diseases and his own observations. It is not difficult to understand why such differences should exist when one recalls that so many descriptions of the brood diseases in the past by Americans have been based largely upon faulty work.

Further on in his paper, Burri gives the microscopic findings and describes the gross appearance of a few larvæ taken from each of the eight samples of sour brood which he examined. He mentions in "sour brood" the yellowish color of the larvæ, the uncapped cells, and the presence of rather long rods. Short rods were also found, resembling in morphology *Bacterium g ntheri*. On account of this similarity, in recording the presence of this latter species, Burri has referred to it as the "g ntheri-forms." These facts concerning the gross appearance of the microscopic findings in "sour brood" suggest strongly that the condition is the same as the foul brood of Cheshire and Cheyne (European foul brood).

In summing up the results of his study on "sour brood," Burri emphasizes two observations: First, that there is a form of disease found all over Switzerland which possesses the characters mentioned for "sour brood"; and, second, that in the condition there is a certain

uniformity in the microscopic findings. There were medium-sized and small bacterial rods present together with forms resembling in morphology *Bacterium g  ntheri*. There was an absence of spores and of the corresponding vegetative forms. It was observed that one group of bacteria may predominate in some samples and another group may predominate in others. Where rods of relatively large size were found in brood which in gross appearance resembled sour brood, it was supposed that a double or mixed infection of foul brood and sour brood was present. This double infection, it was believed, occurred very frequently.

In continuing his bacteriological study of "sour brood" Burri encountered a few rather interesting species. *Bacillus alvei* was present in many samples of "sour brood" examined. From most of the samples examined difficulty was encountered in obtaining cultures of the microorganism to which he refers as the *g  ntheri*-forms. He reports, however, that this difficulty had been overcome and that he had obtained pure cultures of this species. He made some comparisons between the cultures of this species and those of *Bacterium g  ntheri* which resulted in the conclusion that while there was a certain relationship existing between them, the two were not the same.

Burri sums up the results of his study of "sour brood" as follows:

1. There is a disease of the brood accompanied by a rapid growth of bacteria, which have no direct relation with the bacteria of foul brood.
2. The larv   attacked are characterized by the following symptoms: (a) More or less noticeable sour odor; (b) comparatively pale, dirty yellow color; and (c) a great resistance of the chitinous covering which allows the dead larva to be lifted intact from the cell as a moist mass.
3. In microscopic examination the contents of these larv   are characterized by the presence of forms resembling sour milk bacteria (*g  ntheri*-forms) beside medium-sized and small rods. It is characterized also by the absence of large spore-bearing rods and spores.
4. Pure culture experiments with such bacterial material give proof of a certain relationship between the true sour milk bacteria and the *g  ntheri*-forms. The cultures also show that the medium-sized and small rods are strong acid producers. The name "sour brood" is therefore entirely justified.

With respect to the occurrence of "foul brood" and "sour brood" in the same colony one finds the following in Burri's paper:

In describing each attempt to isolate the sour brood *g  ntheri*-forms the rarely expected fact was demonstrated that in a whole series of cases, a growth of colonies of *Bacillus alvei*, the easily cultivated producer of stinking foul brood, was obtained from typical sour broody cells instead of the *g  ntheri*-forms desired. The series of cases of this kind could be greatly increased. Moreover, in the course of my investigations such findings have been repeated such a surprising number of times that I was forced to think there must be some close connection between the two diseases. For some time I was even inclined to believe that the sour brood bacteria represented only a certain stage of development in the foul brood bacteria but gave up this view when the morphological question was explained by means of culture experiments. To-day it can safely be affirmed that foul brood bacteria, sour brood *g  ntheri*-forms, and the

other types of rods found in sour brood cells are independent organisms, each with its own cycle of development. If various pathogenic bacteria are met with in a disease, medical men speak of the condition as a mixed infection. It seems that generally in sour brood we have to deal with such a mixed infection. As already pointed out, I have, occasionally in the microscopic examination, but particularly in the cultural tests of the comb material sent in, encountered the mixed infection of sour brood and foul brood so regularly, that I scarcely expect to meet with a case of pure sour brood. By this I mean a comb with sour brood cells in which at the same time foul brood germs are not to be found. This presumption, however, proved not to be true, for the specimen from Kaltbrunn must be considered as a case of "pure" sour brood. The first specimen from Murten which similarly gave the impression at first of being "pure," had to be considered subsequently to be foul brood, for the second specimen from the same source showed unquestionably the presence of *Bacillus alvei*.

The samples containing dead brood, which Burri studied from May, 1903, to September, 1905, were grouped under four headings, viz, "sour brood," "stinking foul brood," "nonstinking foul brood," and "dead brood free from bacteria."

In summing up Burri's work on "sour brood" the following interesting facts might be mentioned:

1. The origin of the term "sour brood" is not definite.
2. Burri considered three gross characters to be of especial value in the diagnosis of "sour brood"—a sour odor, a lack of ropiness of the decaying larvæ, and a dirty yellow color of the brood recently affected.
3. In "sour brood" were found a large number of short rods which resemble, on microscopic examination, *Bacterium g  ntheri* found in sour milk, and with these he found other rods of medium and large size.
4. When cultures were made from the larv   dead of "sour brood," the *g  ntheri*-forms did not grow as a rule, but in their stead cultures of *Bacillus alvei* appeared sometimes in pure culture.
5. The cultivation of the *g  ntheri*-forms is reported as having been successful.
6. Burri believed that "sour brood" and the "stinking foul brood" are usually found together. This was suggested to him by the frequent presence of *Bacillus alvei* and the *g  ntheri*-forms in the same diseased colony. "Sour brood" was reported to have been found alone in one instance.
7. He grouped the samples of comb which contained dead brood into four conditions, viz, "sour brood," "stinking foul brood," "non-stinking foul brood," and "dead brood free from bacteria."
8. The true menace to bees he believed to be due to a bacillus which is difficult to cultivate.

We are not inclined to agree with all the views expressed by Burri in his work on "sour brood." The condition referred to as "sour brood" and "stinking foul brood" are probably but one disease, European foul brood; the "non-stinking foul brood" is the same as is now known as American foul brood, and the samples which were reported as containing no bacteria together with those which were

received labeled "black brood" were in most instances very probably the so-called pickled brood.

This completes for the present the consideration of the investigations made by Dr. Burri. His work is executed with much care, and his results are correspondingly valuable. For this reason we feel that anything which he writes on bee diseases can be recommended to the bee keepers for careful study.

MAASSEN, JUNE, 1906.

Several interesting papers on bee diseases have been written by Maassen, of Dahlam, Germany. The first paper¹ to be considered is on "foul brood."

Of the samples received from 119 apiaries, 112 were found upon examination to be diseased. Of these 112 samples which were declared diseased, *Bacillus alvei* was found in only 13.

Maassen fed colonies large amounts of cultures of *Bacillus alvei* in both the vegetative and spore form during the brood-rearing season without producing the disease. An attempt was also made to inoculate the brood directly, but negative results were obtained by this method (p. 59). The conclusion was therefore drawn that *Bacillus alvei* had not the significance in brood infection that had ordinarily been attributed to it. In all cases where *Bacillus alvei* was not found there were other spore-bearing species observed. The presence of one species is especially emphasized which offered much difficulty in cultivation on the usual media of the laboratory (p. 60). This species he refers to as *Bacillus brandenburgiensis*. No definite proof was obtained of a causal relation between this spore-bearing species and the disease.

It seemed to Maassen at this time that spore-bearing bacteria were probably only secondary invaders in this disease condition. He was strengthened in his belief by the finding of what he supposed was a protozoan to which he gave the name *Spirochæte apis*. In all brood affected with the disease he records the presence of this microstructure. It was yet to be determined, he says, whether this last finding bore any causal relation to the disease in which it was found.

In this paper by Maassen the following points are of special interest:

1. Maassen was examining samples of brood which were suspected by the bee keepers to be "foul brood."
2. He does not mention two forms of "foul brood."
3. He found *Bacillus alvei* in 13 samples of "foul brood" out of 112 samples diseased.

¹ Maassen, Dr. Albert, June, 1906. Faulbrutseuche der Bienen. Mitteilungen aus der kaiserlichen biologischen Anstalt für Land- und Forstwirtschaft. Heft 2, pp. 28-29.

4. He found in all the samples of foul brood examined, in which *Bacillus alvei* was absent, another species present which offered difficulties in its cultivation on artificial media and refers to the species as *Bacillus brandenburgiensis*.

5. He reports this species to be present in some of the samples, together with *Bacillus alvei*.

6. He used a large amount of the culture of *Bacillus alvei* in the inoculation of healthy bees and did not produce disease.

7. "Foul brood" was not produced with pure cultures of *Bacillus brandenburgiensis*.

8. He was inclined to the belief that bacteria are secondary invaders in "foul brood."

9. He believed that this view was strengthened by the finding of a microorganism to which he gave the name *Spirochate apis*.

10. He reports this microstructure present in all samples of the disease which he had examined up to that time.

MAASSEN, JUNE, 1906.

Another paper appeared by Maassen,¹ in which he briefly refers to a disease which he says is known to the bee keepers as "stone brood."

The condition, he says, is characterized by the hard, leathery, brittle, odorless, and mummylike masses into which the larvæ and pupæ of bees are transformed with no marked change in their form. Accompanying the condition is a higher death rate among the adult bees.

The peculiar change in the brood was attributed to a fungus that grows well at a warm temperature, and whose characteristics when studied in pure cultures were found to be similar to those of *Aspergillus flavus*. The method of transmission of this germ was not determined. According to the observations that were made it was supposed that bees were very susceptible to the disease. This was especially true if the temperature was high or the hive was badly ventilated, and it was therefore recommended that these conditions be avoided in the treatment of the disease. Maassen expresses the belief that "stone brood" has often been referred to by bee keepers as "black brood," "new bee disease," "bee pest," and "pickled brood."

We are not familiar with the condition "stone brood," and we are not aware of its presence in America. The symptoms given do not correspond to those observed in the so-called black brood or in the pickled brood that are met with in this country. It is intimated in Maassen's paper that a publication on the mycotic diseases of bees was being prepared.

¹ Maassen, Dr. Albert, June, 1906. Die Aspergillusmykose der Bienen. Mitteilungen aus der kaiserlichen biologischen Anstalt für Land- und Forstwirtschaft. Heft 2, pp. 30-31.

BAHR, 1906.

Another publication by Bahr¹ appeared in 1906, in which he gives the results obtained from his further investigations. He reports that more than 200 cases of foul brood had been examined. The following points are noted in Bahr's paper:

1. One can not be sure with what disease he was working.
2. He does not always find *Bacillus alvei* in foul brood.
3. With cultures of *Bacillus alvei* he was not able to produce foul brood either by spraying the larvæ or by feeding cultures of the bacillus. He failed also to produce the disease by using the contents of the dead larvæ for spraying or as food in sugar sirup.
4. He suggests that the reason for these negative results may be either that *Bacillus alvei* is not the cause of foul brood or that the proper time or manner in which such infection can be produced experimentally had not been discovered.
5. He did not find any other bacillus as a possible cause of the disorder. *Bacillus alvei* was not found in the eggs or in the sexual organs of the queen, as had been reported by Cheshire (p. 21), Harrison (p. 49), and others.
6. He suggests that possibly the cause of the disease is an ultra-visible virus and that possibly the disease is transmitted through the queen.

It appears likely that Bahr was working with European foul brood, but this is not at present positively known. If he studied American foul brood, he must have overlooked the fact that there are numerous spores (*Bacillus larvæ*) present in the decaying remains of the larvæ which do not grow on the artificial media commonly used. In support of his theory that the disease is transmitted by the queen he says that he has introduced a queen from a diseased colony into a healthy one and produced foul brood as soon as the queen could lay the eggs, and that he has introduced queens from healthy colonies into apparently doomed ones with the result that the diseased colonies quickly recovered.

These experiments should be repeated for a confirmation of the results. If, as is probable, Bahr worked with European foul brood, there were probably other factors present which were not accounted for. His failure to find *Bacillus alvei* in all the samples examined is interesting, and his failure to produce foul brood with cultures of *Bacillus alvei* repeats the experience of some others.

¹ Bahr, L., 1906. Om Aarsagen til Bipesten og dennes Bekæmpelse. Foredrag holdt ved DBF's Diskussionsmøde d. 2 Septbr. 1906 i Esbjerg. Særtryk af Tidsskrift for Biavl. Nr. 17.

PHILLIPS, OCTOBER 3, 1906.

In 1906 a brief circular¹ was issued by this bureau giving the symptoms and treatment of the two brood diseases. This paper is of interest at this time only because it was the first occasion for the use of the names "American foul brood" and "European foul brood" in a publication of the bureau.

Since the name "black brood" had been, on account of an error, applied (p. 45) to the foul brood which Cheshire and Cheyne (p. 25) described, the name "black brood" was no longer needed. The name "foul brood," however, was being applied by the bee keepers (p. 60) to a disease which was clearly different from the foul brood described by Cheshire and Cheyne. This latter disease, therefore, needed a name. The laws that were in existence in some of the States at that time provided for the inspection of apiaries in which foul brood was found. In order that these laws could be interpreted, in accordance with their intent, to cover the brood diseases of an infectious nature, the name "foul brood" was retained in the names of these two brood diseases. To distinguish the two diseases by name, the adjective "European" was selected for the disease which had been early creditably studied by a European (p. 29) and the adjective "American" was selected for the disease which had been studied by an American (p. 62). These names were chosen only after consultation with a number of the leading bee keepers in America, who agreed that the names were well chosen.

The words "American" and "European" were not chosen to suggest a geographical distribution of the two diseases, as the opinion was held that both diseases exist in Europe as well as in America. Concerning the selection of these names the facts were emphasized in the preface of a paper to be discussed later (p. 76).

ERNE, NOVEMBER, 1906.

In 1906 Dr. Erne,² of Freiburg, Germany, reviewed Burri's work on the brood diseases and gave the results of his own investigations. Erne, too, obtained negative results in an attempt to produce "foul brood" with a culture of *Bacillus alvei*. This species was not found by him in 64 samples of "foul brood" received from different parts of Germany. For these reasons he expresses a doubt concerning any etiological relation between the species and the disease as found in Germany. He found, however, in all samples of the disease a bacterium which he thought probably was identical with the one which

¹ Phillips, E. F., October 3, 1906. The brood diseases of bees. U. S. Department of Agriculture, Bureau of Entomology, Circular No. 79. Pp. 5. (Superseded by Farmers' Bulletin 442, U. S. Department of Agriculture, "The treatment of bee diseases.")

² Erne, Dr. November, 1906. Bakteriologische Untersuchungen über die Faulbrut und die Sauerbrut der Bienen. Die Europäische Bienenzucht, pp. 148-151.

Burri observed to be difficult of cultivation. As this species was not obtained in pure culture, no inoculation experiments were made with it. By feeding foul-brood material to ten colonies, however, Erne proved that the disease with which he was working was infectious, since in every case typical foul brood was produced which contained the same bacillus previously observed.

To make clear his position, Erne summarizes as follows:

1. Burri has not furnished proof that sour brood is a contagious disease and that the bacterium described by him is the cause of the same.
2. It is not proven that there is more than one foul brood germ.
3. I consider as the cause of the epidemic foul brood causing the greatest destruction at the present time, a bacillus which I have found in all of my investigations, which can not be cultivated on the usual media, and which may perhaps be identical with the bacillus that Burri found to be difficult of cultivation.

In Erne's paper the following interesting facts are noted:

1. He was working probably only with American foul brood.
2. Erne took exception to the methods used by Burri in the attempt to obtain pure cultures of the bacillus which was found difficult of cultivation.
3. He emphasizes the importance of the experimental inoculations of healthy colonies in the demonstration of the cause of a disease of bees.
4. He did not find *Bacillus alvei* in 64 samples of foul brood examined from Germany.
5. He obtained negative results when healthy bees were fed pure cultures of *Bacillus alvei*.
6. He questioned an etiological relation between *Bacillus alvei* and "foul brood."
7. He demonstrated the infectiousness of foul-brood material by the production of "foul brood" in healthy colonies.
8. He met with a species of bacterium in foul brood which was difficult to cultivate on artificial media.
9. He considered this germ to be the cause of foul brood, although the fact was not demonstrated.
10. Erne did not in his study of "foul-brood" material meet with a microorganism corresponding to *Spirochæte apis*.

While Erne does not devote much time to bee-disease investigations, his writings show that considerable care is exercised in his work. The bee keepers, therefore, will be profited by reading any papers written by this author.

WHITE, NOVEMBER 6, 1906.

In 1906 the manuscript mentioned on page 67 was published as a bulletin.¹ In the preface the reason for the selection of the names

¹ White, G. F., Ph. D. November 6, 1906. The bacteria of the apiary, with special reference to bee diseases. U. S. Department of Agriculture, Bureau of Entomology, Technical Series, No. 14. Pp. 50.

"European foul brood" and "American foul brood" for two of the infectious diseases of the brood of bees is explained.

The technique used by the writer of the bulletin in making the investigations is given in Part I. In this portion also is discussed somewhat the normal flora of the apiary. It was not the intention in making this study of the normal flora to give a complete list of the bacteria which might be encountered, but to study those species which occur most frequently, and to describe them with sufficient care to make their identification possible.

The results of the study indicate that comparatively few bacteria are present in healthy colonies, on combs, in honey, in larvæ, or on adult bees. In the intestine of adult bees, however, there were usually found a very large number of individual bacteria, which, as a rule, however, represented comparatively few species. One species, an anaërobe, is of much interest since it occurs quite constantly and in very large numbers. It might be mentioned that the bees that did not show this intestinal flora were usually the younger adults. A number of fungi and yeasts were also encountered.

The subject-matter in Part II, "The diseases of bees," is not materially unlike that which appeared in earlier publications to which references have already been made. The author of the paper under consideration had reached no definite conclusion concerning the etiological relation of *Bacillus alvei* to European foul brood, the disease in which this species is usually found in large numbers. That any direct causal relation did exist seemed questionable.

In American foul brood, *Bacillus larvæ* was found in large numbers in the larvæ dead of the disease in all the samples examined. Pure cultures of the organism had been obtained, but not in a suitable form for making inoculation experiments. The author of the paper did not feel justified in stating positively that *Bacillus larvæ* is the cause of the disease. All that seemed justified was the statement that the organism had been found constantly present in the disease.

The following brief summary was made of the results obtained from the study of the bee diseases:

- (1) There are a number of diseased conditions which affect the apiary.
- (2) The disease which seems to cause the most rapid loss to the apiarist is European foul brood, in which is found *Bacillus alvei*—first isolated, studied, and named by *Cheshire and Cheyne in 1885.
- (3) The distribution of *Bacillus alvei* in the infected hive is as follows:
 - (a) The greatest number of infecting germs are found in the bodies of dead larvæ.
 - (b) The pollen stored in the cells of the foul-brood combs contains many of these infecting organisms.
 - (c) The honey stored in brood combs infected with this disease has been found to contain a few bacilli of this species.
 - (d) The surface of combs, frames, and hives may be contaminated.
 - (e) The wings, head, legs, thorax, abdomen, and intestinal contents of adult bees were found to be contaminated with *Bacillus alvei*.

(f) *Bacillus alvei* may appear in cultures made from the ovary of queens from European foul-brood colonies, but the presence of this species suggests contamination from the body of the queen while the cultures are being made and has no special significance.

(4) The disease which seems to be most widespread in the United States we have called American foul brood, and the organism which has been found constantly present in the disease we have called *Bacillus larvæ*. This disorder was thought by many in this country and other countries as well to be the foul brood described by Cheshire and Cheyne, but such is not the case.

(5) From the nature of American foul brood it is thought that the organism has a similar distribution to that of *Bacillus alvei*.

(6) It appears that European foul brood was erroneously called "New York bee disease" or "black brood" by Dr. William R. Howard in 1900.

(7) There is a diseased condition affecting the brood of bees which is being called by the bee keepers "pickle brood." No conclusion can be drawn from the investigation so far as to the cause of the disease.

(8) *Aspergillus pollinis*, ascribed by Dr. William R. Howard as the cause of pickle brood, has not been found in this investigation and is not believed by the author to have any etiological relation to the so-called "pickle brood."

(9) Palsy or paralysis is a diseased condition of the adult bees. No conclusion can yet be drawn as to its cause.

(10) Formaldehyde gas, as ordinarily used in the apiaries, is insufficient to insure complete disinfection.

MAASSEN, FEBRUARY, 1907.

In 1907 Maassen¹ reported on his work of the preceding year on foul brood. Samples were received from 100 apiaries. An examination gave evidence of disease in 79 of them. Disease was not found in the other 21. "*Spirochæte apis*" was reported in samples from 67 apiaries. Accompanying it *B. brandenburgiensis* was reported in 66 cases and *B. alvei* in one. *B. alvei* was not found generally in the samples from Germany, occurring only in 11 of the cases.

Among the 100 samples examined there were 2 in which was found a species in almost pure cultures which before had been found accompanied by *Bacillus alvei*. This species Maassen named *Streptococcus apis*. He says that it belongs to the pneumococcus group, being different from other members of the group by its marked peptonizing character. Upon a certain medium he reports that the species could be cultivated very easily. In 10 cases in which *B. alvei* was found *Streptococcus apis* was reported in 8. No conclusive results were obtained in his attempts to demonstrate the relation between any of the organisms and the disease condition.

In his report the following points of special interest are noted:

1. Maassen did not express any suspicion that two distinct infectious diseases might be present in the condition he was studying as foul brood.

2. He reports the presence in samples from 67 apiaries of a micro-organism which he had previously named *Spirochæte apis*, and with

¹ Maassen, Dr. Albert, February, 1907. Über die sogenannte Faulbrut der Honigbienen. Mitteilungen aus der kaiserlichen biologischen Anstalt für Land- und Forstwirtschaft. Heft 4, pp. 51-53. 6 figs.

it he finds associated *Bacillus brandenburgiensis* in 66 cases and *Bacillus alvei* in one case.

3. He found *Bacillus alvei* in 11 cases of diseased brood. The majority of these samples probably were from apiaries affected with European foul brood.

4. He observed and cultivated a species which he named *Streptococcus apis*. This species, he states, belongs to the pneumococcus group and is easy of cultivation. In 10 samples in which *Streptococcus apis* was found *Bacillus alvei* was found in 8.

5. He states that he had not reached a final conclusion concerning the relation between the microorganisms and the disease encountered.

IMMS, JUNE, 1907.

The Board of Agriculture and Fisheries of Great Britain requested Mr. A. D. Imms, of Christ College, Cambridge, to make a study of the cause and nature of a disorder among bees. References to this disorder have been made in the last few years as the Isle of Wight disease. Imms¹ made a report on his work in 1907.

From this report an idea of the rapid losses which were attributed to the disease can be obtained. It is stated that the disease was so prevalent that it seemed almost impossible to keep a colony healthy for 12 months. Seventy colonies were reduced to 8 in two years. One bee keeper lost 20 colonies out of 22. Three other bee keepers in the same district lost their entire apiaries, consisting of 12, 8, and 4 colonies, respectively. Another bee keeper lost over 50 colonies and about a dozen other bee keepers had no bees left.

Imms gives the following in his description of the symptoms of the disease:

The earliest noticeable symptom of the disease is the inability of the affected bees to fly more than a few yards without alighting. As the disease progresses, the bees can only fly a few feet from the hive and then drop and crawl about aimlessly over the ground. They are often to be seen crawling up grass stems, or up the supports of the hive, where they remain until they fall back to the earth from sheer weakness, and soon afterwards die. In a badly infected stock great numbers of bees are to be seen crawling over the ground in front of the hives, frequently massed together in little clusters, while others remain on the alighting board. If the hives be opened, numbers of diseased individuals will be often met with inside. They are found clustered together around the queen and show very little inclination for movement until disturbed and are entirely unable to fly. Badly diseased individuals show very little inclination for stinging; those that are less severely attacked often sting very actively.

If a badly diseased bee be carefully examined it will be seen to have lost its power of flight, and it crawls about with the hinder extremity of the body dragging on the ground; frequently it walks about with its wings "out of joint," the hind wings protruding obliquely upwards and above the anterior pair. The only other external symptom of the disease is seen in the abdomen, which is frequently distended beyond

¹ Imms, A. D., June, 1907. Report on a disease of bees in the Isle of Wight. Journal of the Board of Agriculture, Vol. XIV, No. 3, pp. 129-140, 4 figs.

its normal proportions. This distension, however, is not by any means constant, and was chiefly noticed in the case of the native bee; in the half-breed with the Italian bee, with its longer and slightly more slender abdomen, no unusual distension could be observed.

The disease appears to differ from what is usually termed "bee-paralysis," in that the infected individuals do not exhibit the characteristic black and shiny appearance, and neither I myself, nor any bee keepers who have paid attention to the disease, have observed the curious trembling motion of the limbs and body which is regarded as a symptom of that disease.

The disease appears to be entirely confined to the adult bees, the brood remaining unaffected. I have conducted a microscopical examination of a large number of eggs, larvæ at all stages of development, and pupæ, and have failed to detect anything of a pathological nature among the brood. All had the characteristic pearly white appearance of healthy specimens although belonging to a badly infected hive. The eggs were undergoing development and showed not the slightest trace of discoloration or shriveling, the larvæ were healthy in every way and were coiled up in their normal attitude, and nothing wrong could be detected with the pupæ or the newly hatched bees.

In describing the "Nature of the disease" Imms writes in part as follows:

The disease is eminently one of the digestive system and might be described as being a condition of enlargement of the hind intestine. Over 150 diseased bees have now been examined and all have been found to exhibit the same symptoms.

The author states that the bacteriological work on the disease was in progress. The work which had already been done demonstrated the presence of a large number of bacterial rods. No conclusion was reached as to the cause of the disease, nor had any remedy been found in the treatment that was successful in the hands of all bee keepers.

Some of the more important points in the paper might be summarized as follows:

1. The disease, so far as was determined, was of recent origin.
2. The disorder described seemed to be very rapidly fatal to adult bees. The brood seemed to be unaffected.
3. To Imms the trouble seemed to be neither dysentery nor the so-called paralysis.
4. No conclusion was reached as to the cause of the disorder.
5. No treatment was demonstrated to be successful.

WHITE, JULY 29, 1907.

On July 29, 1907, there was issued a circular¹ briefly describing some experiments which demonstrated for the first time the cause of American foul brood. Although spores had been observed in very large numbers in the larvæ dead of this disease, no satisfactory medium had yet been devised by which pure cultures could be obtained that were suitable for purposes of experimental inoculations.

¹ White, G. Franklin, July 29, 1907. The cause of American foul brood. U. S. Department of Agriculture, Bureau of Entomology, Circular No. 94. Pp. 4.

The way by which this difficulty is overcome is reported in the publication under consideration. Young pupæ were used in making the medium. These were picked from a comb containing healthy brood, crushed, strained through cheesecloth, and then diluted by adding water equal to from 20 to 50 times the volume of the crushed brood used. This solution was then passed through ordinary filter paper and subsequently through a Berkefeld filter. In this way a sterile filtrate was obtained. About 2 c. c. of the sterile filtrate was then added by means of a sterile pipette to liquefied agar which had been cooled to 45° or 50° C. If pure cultures were desired, agar tubes thus prepared were inoculated with a small amount of diseased brood and plates were poured. If, however, culture growth was desired for the inoculation of bees or experimental animals, it was obtained from these specially prepared agar tubes by first inclining them and then securing the growth by inoculating the surface of the inclined agar with a pure culture of *Bacillus larvæ* obtained from the plates. At no time was this special medium to reach a high temperature.

Two colonies were now fed the scales of American foul brood, suspended in sirup. American foul brood resulted from these inoculations with symptoms the same as are found in an apiary in which the disease appeared through the natural means of infection. Similar results were reported by Erne (p. 76). These experiments were sufficient to prove that American foul brood can be produced experimentally by feeding; also, that the scales of the disease contained the virus.

Having demonstrated the fact that American foul brood can be produced by feeding and having obtained pure cultures of *Bacillus larvæ* in suitable form for inoculation purposes, the next step to be taken, very naturally, was to inoculate healthy colonies with pure cultures of *Bacillus larvæ*. This was now done, and as a result of such inoculations American foul brood was produced with symptoms identical with those produced when the scales were used in feeding. The decaying brood in the disease thus produced contained the large number of spores that are always found in brood dead of this disease, and from the diseased material pure cultures of *Bacillus larvæ* were obtained.

The results obtained from these experiments in which pure cultures of *Bacillus larvæ* were used in making the inoculations justified for the first time the statement that American foul brood was caused by a specific microorganism.

It seemed to the author of the circular that probably the species which had given different workers considerable difficulty in cultivation, in many cases at least, was nothing other than *Bacillus*

larvæ. The "microorganism" named *Spirochæte apis* by Maassen (p. 72) was shown to be giant whips which have their origin in the growth of *Bacillus larvæ*.

PHILLIPS, DECEMBER 31, 1907.

In connection with the study of American foul brood it was noticed that the scales formed by the drying down of the dead larvæ are not destroyed if the comb becomes infested with either of the two wax moths. These observations were recorded in a publication¹ of this bureau. Sometimes it is desirable to have the dried scales of American foul brood in large quantities. These can be easily obtained free from the comb by allowing a well dried and badly diseased sample to become infested with wax moths.

MAASSEN, 1908.

Another paper² by Maassen appeared in 1908. In his former publications this author has dealt with only one form of foul brood. In this paper, however, he states that two forms of the disease have been known for many years, a "mild" form and a "virulent" one.

Maassen's description of the gross appearance of the brood affected with the "mild" form is similar to that given by Dzierzon (p. 18) and others. The disease therefore is quite probably European foul brood. This view is further strengthened by the bacteriological examinations which he reports. His description of the "virulent" form is also similar to that given by Dzierzon (p. 18) and others. The condition is most likely, therefore, American foul brood.

Following the discussion of these two forms of "foul brood" Maassen discusses the etiology of "foul brood." He expresses the belief that foul brood is a disease of the digestive apparatus of the larvæ and can be produced by various causes. As producers of "foul brood" *Bacillus alvei*, *Streptococcus apis*, and *Bacillus brandenburgiensis* are mentioned by him. Besides these three species he reports the presence in the diseased brood of a species of yeast and spore-bearing bacilli. *Bacillus alvei* and *Streptococcus apis* are reported to have been found in both forms of foul brood, while *Bacillus brandenburgiensis* was found in only one of them.

In that form of the disease in which uncapped brood seemed mostly to be affected, Maassen reports the presence of *Bacillus alvei* in 51 samples out of the 53 examined. When *Bacillus alvei* predominated in the sample, he interpreted the odor as being more "sweat-like" in character than when *Streptococcus apis* was in predominance; and

¹ Phillips, E. F. December 31, 1907. Wax moths and American foul brood. U. S. Department of Agriculture, Bureau of Entomology, Bulletin No. 75, Part II. Pp. 19-22.

² Maassen, Dr. Albert, 1908. Zur Ätiologie der sogenannten Faulbrut der Honigbienen. Arbeiten aus der kaiserlichen biologischen Anstalt für Land- und Forstwirtschaft. Bd. VI, Heft I, pp. 53-70. 2 pls.

when the latter species predominated the odor was likened to that of sour paste. In samples from two apiaries Maassen failed to find *Bacillus alvei*, but found *Streptococcus apis* in large numbers. The two cases in which *Bacillus alvei* was absent were suspected of being the sour brood referred to by Burri (p. 68). Maassen was inclined to believe that the latter condition is more widespread in Switzerland than in Germany. In 41 samples of the 51 containing *Bacillus alvei*, the species was accompanied by *Streptococcus apis*. The relative number of *Bacillus alvei* and *Streptococcus apis* varied.

The "guntheri-forms" mentioned in Burri's paper (p. 69) are very probably the species to which the name *Streptococcus apis* Maassen has been applied. Maassen expresses a similar belief. The following description of *Streptococcus apis* is an abbreviation of the one by Maassen.

Occurrence.—This species is found in "foul brood," occurring most frequently in that form in which the larvæ when attacked are uncapped.

Morphology.—In form it is not perfectly spherical but is a lancet-like, pointed coccus that appears as either a Diplococcus or a Streptococcus in the body of the larvæ as well as in artificial media. A capsule is present.

Gram's stain.—The organism is not decolorized by gram's method.

Oxygen requirements.—It grows aërobically as well as anaërobically.

Bouillon.—The medium becomes at first turbid, and later a deposit forms at the bottom of the tube. Reaction is but little changed.

Glucose, lactose, saccharose, galactose, levulose, and mannite bouillons.—Increased growth takes place in these bouillons with the formation of acid.

Agar slant.—A thin iridescent growth takes place. The condensation water is clouded with a sediment present.

Blood serum.—There is a perceptible growth. The colonies are droplike. No liquefaction of the medium takes place.

Potato.—The organism grows well on this medium.

Milk.—Growth takes place rapidly. After 24 hours the casein is coagulated and later some of the coagulum peptonizes.

Gelatin.—After about 40 hours at 20° C. a whitish-gray growth is observed with a beginning liquefaction of the medium.

Indol.—Indol is not formed.

Nitrates.—Nitrates remain unchanged.

Disinfectants.—This species proved very resistant to drying. After three-fourths of a year of drying the organism was not dead.

Burri (p. 70) met with some difficulty in the cultivation of the species to which he referred as the *guntheri*-forms. In a few cases, Maassen apparently had some difficulty also with his *Streptococcus apis*, but in most cases no difficulty was encountered. The difficulty,

Maassen says, was obviously due to an acid which was present. He likened the condition to that obtained in cultures in those artificial media in which a sugar is present. Maassen suggests that the death of *Streptococcus apis* under these conditions is not without significance if this organism is the cause of the disease.

The feeding of pure cultures of *Streptococcus apis* to healthy colonies gave negative results. He reports that negative results were obtained also when healthy colonies were fed larvæ containing the cocci with no *Bacillus alvei* present. When similar larvæ, however, were fed to healthy bees together with a suspension of the spores of *Bacillus alvei* he reports that the disease was produced.

Having considered the etiology of the "mild" form of foul brood (European foul brood), Maassen took up for consideration the cause of the so-called "virulent" form of the disease (American foul brood). This latter disease, he says, is far more widespread in Germany than is the former. From 347 samples of diseased brood examined in five years, 294, almost 90 per cent, were affected with the "virulent" form of the disease. In this form he usually found *Bacillus brandenburgiensis*. This species was so named by him because his first experience with it was in a sample from the Province of Brandenburg, Prussia. Maassen describes the morphology and cultural characters of *Bacillus brandenburgiensis*. He says that this species is the cause of the foul brood most commonly found in Germany.

Maassen also says that he found spirochæte-like forms (p. 73) in the unstained decaying "foul-brood" mass. He considers them a good diagnostic agent in the virulent form of the disease. He says further that in the progress of his investigations he found *Spirochæte apis* to be nothing more than tufts of the flagella of *Bacillus brandenburgiensis* (p. 82). He also says that after great difficulty two media were found on which *Bacillus brandenburgiensis* grew well. One was agar made from bee larvæ (p. 62), and the other was agar made from the brains of calf or of pig. Maassen reports that he has produced disease by feeding cultures of *Bacillus brandenburgiensis*. Each colony fed received the cultures from 10 to 20 tubes. When considerable culture was fed the disease appeared in from 6 to 10 days after the feeding of the colony. He states that the disease is present in America, and that a bacillus has been found in it which has been named *Bacillus larvæ*.

Maassen has therefore confirmed most of the facts stated in the paper (p. 80) which was received by him at least four months before his was published.

The following is a brief summary of Maassen's paper:

1. He mentions that he has encountered in his studies two forms of foul brood. These were described by Dzierzon and others.

2. The form which seems to be European foul brood he refers to as the "mild" form; and the other one, which seems to be American foul brood, he refers to as the "virulent" form.

3. In the "mild" form he finds *Bacillus alvei* and *Streptococcus apis*, together with a few other species.

4. In two instances he did not find *Bacillus alvei* present, but did find *Streptococcus apis*. This condition he believes to be the "sour brood" of Burri.

5. In a few cases only he reports difficulty in obtaining cultures of *Streptococcus apis* on artificial media.

6. In the disease (American foul brood) which is most common in Germany, Maassen finds a species which he calls *Bacillus brandenburgensis*.

7. In this disease he also finds *Bacillus alvei* generally associated with *Bacillus brandenburgensis*.

8. In a few samples he found *Streptococcus apis* accompanying *Bacillus brandenburgensis*.

9. In his experimental inoculations, he obtained positive results when *Bacillus brandenburgensis* in either the vegetative or spore form was fed to a healthy colony.

10. He obtained negative results when healthy colonies were fed cultures of *Streptococcus apis*.

11. He failed to produce disease by feeding to the healthy colonies dead brood containing *Streptococcus apis* but no *Bacillus alvei*.

12. He reports positive results when the spores of *Bacillus alvei* were fed together with dead brood containing *Streptococcus apis*.

MAASSEN, SEPTEMBER, 1908.

Maassen¹ published another paper in 1908. He reviews briefly the history of the study of foul brood. An attempt was made to learn of the distribution of the diseases in Germany. For this purpose letters were sent to bee keepers in various parts of the country, making inquiry into the disease conditions of the apiaries. Answers were received from two States. He obtained data, however, from other sources which caused him to believe that foul brood is frequent in almost all of the German States. A review is then made of his own investigations relating to foul brood.

WHITE, DECEMBER 26, 1908.

The object of a paper² read before the National Bee Keepers' Association on October 14, 1908, was to direct the attention of bee

¹ Maassen, Dr. Albert, September, 1908. Über die unter dem Namen "Faulbrut" bekannten seuchenhaften Bruterkrankungen der Honigbiene. Mitteilungen aus der kaiserlichen biologischen Anstalt für Land- und Forstwirtschaft. Heft 7. Pp. 24. 4 Tafeln. July, 1909. 2 Auflage. Pp. 31. 4 Tafeln.

² White, G. Franklin, Dec. 26, 1908. The relation of the etiology (cause) of bee diseases to the treatment. U. S. Department of Agriculture, Bureau of Entomology. Bulletin No. 75, Part IV, pp. 33-42. Reprinted. Annual Report of the National Bee Keepers' Association for 1908. Pp. 60-65. U. S. A.

keepers to the important relation which exists between the etiology of a disease and its rational treatment.

The author at first deemed it advisable to direct the attention of his hearers to a consideration of the nature of disease. A brief discussion is then given of the etiology of diseases, illustrating the statements made mainly by citing phenomena observed in bee diseases. In discussing the etiology, the usual division into predisposing and exciting causes is made. Of the predisposing causes of diseases it seemed well to mention age, sex, heredity, race, climate, and pre-existing disease, inasmuch as these factors may be active in one or more of the diseases of bees. Of the exciting causes of disease, food and microorganisms are the only ones mentioned, since food, bacteria, protozoa, and fungi have been thought by one writer or another to be the direct exciting cause of bee diseases. A brief reference is then made to the nature of bacteria, protozoa, and fungi.

Mention is made in the paper of the fact that a microstructure had been encountered in the investigations of European foul brood which had failed to grow on artificial media. This was referred to as "*Bacillus Y.*" Some hope was entertained that it might sometime be proved to be the exciting cause of the disease. The great resistance exhibited by the spores of *Bacillus larvæ* toward disinfectants was emphasized by citing some preliminary experiments.

The following are some of the facts to which the attention of the bee keepers was directed:

1. Disease is nothing more than a departure from a state of health.
2. The departure is the result of some cause.
3. The cause is, as a rule, a combination of factors which constitute what is known as the etiology. Age, sex, race, and climate seem to figure as predisposing factors in bee diseases. Bacteria, protozoa, and fungi have all been studied as probable exciting causes. Bacteria are the only kind of a microorganism that has been proven to be the cause of a bee disease.
4. Comparatively little is known of the etiology of bee diseases—a statement which, as one becomes familiar with the diseases of other animals and man, is found to be true for them also.
5. The exciting cause of but one bee disease is positively known.
6. A rather interesting microstructure was encountered in European foul brood which had refused to grow when sown upon artificial media. This is referred to as "*Bacillus Y.*"
7. A treatment, either preventive or curative, can best be devised only after the cause is determined.
8. Before treating a disease, a diagnosis is advisable. This can most accurately be done by knowing the cause and finding it in the diseased body.

9. The conclusion drawn is that in a knowledge of the causes of bee diseases lies hope for their control.

MALDEN, FEBRUARY, 1909.

In 1909 Dr. Malden, of Cambridge, England, made a report¹ on his investigations of a disease which appeared on the Isle of Wight. A paper by Imms (p. 79) discussing this disorder has already been considered.

Malden went to the island in May, 1908, and by interviewing the bee keepers and inspecting colonies found that the disease had apparently quite died out. The disease had been seen, however, in March and early April of that year. After a short period of apparently complete absence the disease again appeared about the middle of June, 1908.

Malden states that as a rule the disease causes greater losses during the summer than in winter. The reverse, however, has been noted at times. May and June are according to most observers the months during which the disease is usually most rapidly fatal. Infected colonies are not always destroyed. They may recover but are subject to a later attack by the disease.

Malden's investigations into the cause of the disease include a study of the gross and microscopical anatomy of the diseased bee, together with a bacteriological study of it. In his bacteriological study one species was encountered to which, on account of its resemblance to *Bacillus pestis*, the supposed cause of bubonic plague, he gave the name *Bacillus pestiformis apis*. The morphology, cultural characters, and pathogenic properties of this bacillus are given as follows by Malden:

It is an aerobic, non-motile, Gram negative, non-acid-fast, short, broad bacillus, varying in its morphological appearances upon different media. No flagella could be demonstrated. On *agar* it grows fairly well, forming in twenty-four hours medium-sized (largest 0.1 cm. in diameter), round, white or slightly yellowish, smooth, glistening, flattened, dome-shaped colonies. On further growth the colonies do not increase much in size, and unless very thickly sown they show little tendency to coalesce. After twenty-four hours' growth the bacilli are of medium length (1-1.5 μ), broad, and with distinctly rounded ends. Many of them are distinctly oval. They have a tendency to stain better at the ends than in the middle (polar staining). Occasionally the lightly staining central portion appears as a distinct band, especially when the organism is lightly stained. After seven days' growth very little general change is noticed, though a few large involution forms make their appearance. On *gelatin* growth takes place rapidly in the form of colonies, resembling those produced on *agar*. The organisms are more rounded than on *agar*, being distinctly oval in shape, and polar staining is not so marked. On *potato* a considerable raised cream coloured growth is produced in twenty-four hours at 37° C., which continues to spread. The bacilli are larger than when grown on *agar*, but the light central band is not quite so

¹ Malden, Walter, M. A., M. D., February, 1909. Further report on a disease of bees in the Isle of Wight. *Journal of the Board of Agriculture*, Vol. XV, No. 11, pp. 809-825.

well defined. When stained by Neisser's method, a few show polar bodies (metachromatic granules). Involution forms, many of which grow to a large size, appear rapidly, and are very abundant after forty-eight hours' growth. In broth at 37° C. a cloudy growth is first formed, but later the medium becomes clearer, and a considerable yellowish, flocculent deposit is produced. A surface film is usually seen after a few days' growth, and may be very marked. If the tube is shaken, the film sinks, or is broken up, but another forms. The bacilli resemble those found on gelatin cultures. No acid or gas is produced in media containing *glucose*, *lactose*, *saccharose*, *dulcite*, *mannite*, *maltose*, *dextrin*, or *glycerine*.

Pathogenic Properties.—A single infection experiment was made with a culture of this bacillus. A healthy stock of bees was placed in a hive in a green-house. After a few days all the openings were closed with muslin, and the bees fed on syrup. When the bees had become accustomed to this treatment, broth cultures of the bacillus were mixed with the syrup. Within a few days considerable numbers had died, and specimens of apparently diseased bees showed the bacilli in their chyle stomachs, which also showed the fragile condition found in naturally infected bees. Distention of the colon could not be taken as a diagnostic point, as this condition was found to be present in healthy specimens of this stock taken from the hive before the experiment was started. The majority of the bees showed no signs of disease a week after feeding was commenced.

The results of the anatomical and bacteriological studies of this disease by Malden are clearly set forth in the following quotation from his paper:

Anatomically the majority of diseased bees show great distention of the colon, and a fragile condition of the chyle stomach. In many obtained from diseased stocks, and apparently suffering from the disease, distention of the colon is absent. All the organs, except those just mentioned, are normal. Healthy bees confined to their hives for a few days very closely resemble diseased bees in regard to the condition of their intestinal canals. It is impossible, therefore, both from the clinical and anatomical points of view, to diagnose whether any given bee is suffering from the disease or not.

Histologically the chyle stomach appears to be the only organ affected, and bacteriologically plague-like bacilli were frequently encountered in it, in some cases apparently within the epithelial cells. These bacilli were not found either in the brood of diseased hives or in the chyle stomachs of healthy bees. For these reasons I am inclined to regard these organisms as the cause of the disease. I am, however, well aware that I have not fully established their relationship to the disease, since I have not been able to demonstrate them in every case either microscopically or by culture, or to find, except in very advanced cases, any very definite lesions constantly associated with their presence. I feel that my inability to discover any means of cultivating the organism with certainty even from chyle stomachs, in which it was present in abundance as shown by microscopical preparations, constitutes the most serious difficulty in establishing its relationship to the disease. By their morphology alone, few pathogenic bacteria can be recognized, since morphologically indistinguishable, but non-pathogenic, organisms are frequently encountered. Consequently, until some satisfactory cultivation methods have been discovered, the bacteriological diagnosis of this organism must in most cases remain in doubt, for organisms simulating it in morphology probably exist.

Concerning this disease and its cause the following points are to be emphasized:

1. Malden found the disease which Imms reported still present on the Isle of Wight.

2. The evidence obtained indicates that the disease is infectious.

3. An organism was encountered in a number of diseased bees, to which Malden gave the name *Bacillus pestiformis apis*.

4. This organism was not proven by Malden to be the cause of the disease.

ZANDER, AUGUST, 1909.

In 1909, Dr. Zander, at Erlangen, Germany, wrote an interesting paper¹ concerning the cause of a disease affecting the adult honey bee.

From his studies Zander was led to believe that there are two forms of dysentery. One form he considers to be noninfectious and comparatively harmless. The cause of this form is attributed to various conditions, such as disturbance of the colony, queenlessness, improper winter stores, deficient opportunity for a cleansing flight, etc. A second form of dysentery Zander refers to as the malignant form. In referring to the virulence of this form Zander says that it has all the characteristics of an infectious disease, destroying more colonies in one spring in the neighborhood of Erlangen than foul brood had during the entire preceding year in the whole State of Bavaria.

During his investigations in 1907 Zander found in the mid-gut of diseased bees a protozoan to which the name *Nosema apis* was given. This portion of the intestine of all the bees which died of the "virulent" form of dysentery was found to be milk-white and completely filled with *Nosema* spores. Queens from dysenteric colonies were examined and found also to be infected with the protozoan. No drones were found infected. This was supposed to be due to the fact that there are no drones during the active dysenteric season. The excrement from the bees also contained numerous spores.

Zander expresses the belief that the transmission of the disease is made possible by the deposit of excrement on the frames and walls of the hive, which takes place when no opportunity is afforded the bees for a cleansing flight. The mutual feeding practiced by bees hastens, it is suggested, the spread of the infection. The bees are supposed to be subjected to further infection from without on account of the spores that are spread about through the medium of the excreta of the flying bees. Robbing also is given as a fruitful means of transmission. The use of contaminated combs from apiaries in which the infection is present is also thought to be a means for the spread of the disease.

The prognosis is supposed to depend somewhat upon conditions. Long, hard winters are given as a cause of very heavy losses with this disease. If, on the other hand, the spring is warm with a good flow

¹ Zander, Dr. Enoch, August, 1909. Tierische Parasiten als Krankheitserreger bei der Biene. Münchener Bienenzeitung, Heft 9. Pp. 11.

and the old bees are rapidly replaced by young healthy ones, the young bees remain healthy unless a second infection takes place. It is suggested that if this second infection takes place it asserts its presence about four weeks after the first outbreak. It is then commonly thought by the bee keeper to be a different disease, the one to which the name "May disease" is sometimes applied. In the so-called "June disease" Zander reports the presence of infection with *Nosema apis* also.

Zander performed some inoculation experiments for the purpose of demonstrating the relation of *Nosema apis* to the "virulent" type of dysentery. He describes one in which infected material was fed in honey to a colony free from disease. The excrement from bees affected with dysentery, together with bees so affected, was ground and added to diluted honey. The mixture was filtered and put into two combs, and the combs were placed into a queen-right colony, which had been examined and found to be free from disease. Three days later the bees began to die with all the symptoms of "May" and "June" disease. Many dead and dying bees were found in the yard in the direction of flight of the bees. A microscopic examination demonstrated the presence of *Nosema apis* in these bees. After eight days the mid-gut of most of the diseased bees was milk-white. The colony became weaker and weaker, and at the end of a month only a handful of bees remained.

Zander concludes from his work that *Nosema apis* is the exciting cause of the infectious form of dysentery.

The following is a brief summary of Zander's first paper on *Nosema apis* and the disease with which he found it associated:

1. Zander discovered a protozoan that attacks the epithelial cells of the mid-gut of the adult honey bee. To this protozoan was given the name *Nosema apis*.

2. He discusses dysentery of bees under two forms—a mild form and a virulent one.

3. He believes the mild form to be noninfectious and probably due to a number of different causes; the infectious or virulent form he believes to be due to *Nosema apis*.

4. He is inclined to believe that this infectious form is the same disorder as the one to which "May disease" and "June disease" has frequently been applied.

5. It should be noted that Zander does not claim to be working with a new disease, but is simply seeking to determine the cause of dysentery—a disease with which most bee keepers have had experience.

MAASSEN, MARCH, 1910.

Another paper ¹ by Maassen appeared in 1910.

At this time the content of the intestinal tract of bees taken from colonies affected with different brood diseases was made the subject of study.

When bees were examined that were taken from colonies suffering from "sour brood," Maassen reports the presence of *Streptococcus apis*. This species thrives well, he says, in the intestine, and its power to grow upon artificial media is not lost (p. 84). Likewise, he reports that the spores of *Bacillus alvei* will develop and the organism grow in the intestine of adult bees. Confined bees, it is stated, showed the presence of these two species for weeks in the intestine.

In the case of American foul brood, Maassen reports that the spores of *Bacillus brandenburgiensis* do not germinate in the intestine of the adult bee, nor do the vegetative forms multiply there. He reports that after a few days a noticeable decrease is to be observed in the number of spores present. These observations caused Maassen to caution those treating bee diseases against the probability of infection from these germ carriers.

The paper also contains a report on the samples received for diagnosis. Material was received from 85 apiaries. When examined, 66 of the samples gave evidence that disease was present. Forty-five are reported as American foul brood, one as a mixed infection of American foul brood and European foul brood, 10 as European foul brood, and 10 as a mixed infection of European foul brood and sour brood.

Here the following points are to be noted:

1. Maassen reports that *Bacillus alvei* is found in the intestine of adult bees taken from a colony affected with European foul brood and that this species multiplies in this locality.

2. He reports that *Streptococcus apis* is found in the intestine of bees that are taken from colonies affected with sour brood and that this species also multiplies in this locality.

3. He reports that the spores of *Bacillus brandenburgiensis* do not increase in the intestine of the adult bee.

4. These germ carriers, Maassen suggests, must not be overlooked in devising methods of treatment.

¹ Maassen, Albert, March, 1910. Untersuchungen über die Epidemiologie der sogenannten Faulbrut der Bienen. Mitteilungen aus der kaiserlichen biologischen Anstalt für Land- und Forstwirtschaft, Heft 10, pp. 37-39.

MAASSEN AND NITHACK, MARCH, 1910.

Simultaneously with the paper just considered there was published a paper¹ on bee dysentery by Maassen and Nithack. Dead adult bees from entirely isolated localities were received and examined. There was a history of supposed poisoning accompanying the bees. No cause for their death, however, could be found. It is recorded that no *Nosema apis* was found.

The first dysentery observed by these men was in two colonies taken from different apiaries. One was a queenless two-frame nucleus and the other a queen-right colony of six frames. These two colonies were transferred to wire cages. After about three weeks symptoms of dysentery were observed. At the beginning of the spotting *Nosema apis* was not found in the excrement, but could be demonstrated in the mid-gut. Several days later, when the intestine showed the appearance described by Zander, the parasite was found in the intestine.

These findings caused Maassen and Nithack to confine in wire cages a series of small queenless colonies. These cages were kept in a room whose temperature ranged from 14° to 16° C. The bees were obtained from different sources, and all chances of becoming infected from food, hives, or combs subsequent to being taken into the room were excluded. The results obtained from this experiment were similar to those of the preceding one. Other experiments somewhat similar were performed.

These men report that in many colonies in which no visible signs of dysentery were present there were found bees containing *Nosema apis*. They believe that among bees this protozoan is widely distributed. Up to the time of their writing they had not failed to find it in colonies that were suffering from dysentery.

MALDEN, JUNE, 1910.

In 1910 Malden in a paper² gave a good brief review of the status of the present knowledge of bee diseases. He gives some further observations concerning the Isle of Wight disease. Referring to *Bacillus pestiformis apis* (p. 87) he writes in part as follows:

This organism may frequently be found to have penetrated between the cells of the lining membrane of the chyle stomach and to be present in large numbers in the loosened tissue behind the secreting cells. It has been found present in about 60 per cent. of all the bees affected with this disease which have been examined. * * * It appears highly probable that this organism is the cause of the disease, but up to the present time no infection experiments have been successful in producing the complaint in healthy stocks, so that its relation to the disease cannot be said to be proved.

¹ Maassen and Nithack, March, 1910. Über die Ruhr der Bienen. Mitteilungen aus der kaiserlichen biologischen Anstalt für Land- und Forstwirtschaft, Heft 10, pp. 39-42.

² Malden, Walter, M. A., M. D., June, 1910. Diseases of bees. Reprinted from The Journal of Economic Biology, Vol. V, Pt. 2. Pp. 41-48.

Malden reports that the disease had within the previous two years spread from the Isle of Wight to the mainland (England). There seems to be evidence that the virulence of the disease is less than when first observed on the Isle of Wight.

ZANDER, 1910.

Zander in 1910 in a publication ¹ gives a good brief review of the work that has been done on the cause of the brood diseases. The disease in which *Streptococcus apis* is found Zander refers to as "sauerbrut"; the disease which he refers to as "faulbrut," we call American foul brood; and we diagnose as European foul brood what he refers to as "brutpest."

ZANDER, 1911.

In 1911 Zander writes ² of the diseases and enemies of the adult bees. The morphology, life history, and distribution of *Nosema apis* (p. 89) had been the subject of further study by him and in this publication he gives the results of his work.

A BRIEF CHRONOLOGICAL SUMMARY OF THE WORK ON THE CAUSES OF BEE DISEASES.

THE DIFFERENT DISEASES THAT ATTACK BEES.

That bees suffer from disease is recorded in the writings prior to the Christian era. It is not known, however, which diseases are referred to.

Schirach (p. 13) in 1771 classified the diseases of bees. In his classification he mentions, among other diseases, dysentery and foul brood.

Just when and by whom it was first recognized that foul brood was of two forms is not known. It would seem that Schirach, in 1771, observed that foul brood was not always the same. One finds that Leuckhart (p. 14) in 1860 and Molitor-Mühlfeld (p. 14) and Preuss (p. 15) in 1868, all indicated by their writings that they considered foul brood to be of more than one form.

Dzierzon (p. 18), in his "Rational Beekeeping" in 1882, describes two forms of foul brood. The descriptions of the two forms agree very closely with those of European foul brood and American foul brood.

Cheshire (p. 19) began to write early in the year 1884 of two forms of foul brood, but before the close of the year he (p. 22) declared that there was only one form.

¹ Zander, Dr. Enoch, 1910. Die Faulbrut und ihre Bekämpfung. Part I. Handbuch der Bienenkunde in Einzeldarstellungen. Mit 4 Tafeln und 8 Abbildungen nach Originalen des Verfassers. Pp. 31.

² Zander, Dr. Enoch, 1911. Krankheiten und Schädlinge der erwachsenen Bienen. Part II. Handbuch der Bienenkunde in Einzeldarstellungen. Mit 8 Tafeln und 13 Abbildungen grösstenteils nach Originalen des Verfassers. Pp. 40.

During the following decade there continued to be different opinions entertained as to the classification of the infectious brood diseases.

Many bee keepers were convinced from their experience with the diseases of the brood that there existed two distinct infectious disorders (p. 60). By a more careful study of these diseases it has been shown positively that the brood is attacked by more than one infectious disease.

These diseases as understood by the writers of this bulletin are briefly discussed on pages 11 and 12.

The classification of the adult bee diseases is yet very unsatisfactory.

THE CAUSES OF BEE DISEASES.

As exciting causes of bee diseases different workers have from time to time suggested different agents.

Schirach (1771) (p. 13) suggested two causes for foul brood—improper food as one, and a fault of the queen as a second.

Leuckart had at first inclined to the view that the infectious foul brood was due to a fungus, but from his observations made in 1860 (p. 14) he arrived at the conclusion that this was not true.

Molitor-Mühlfeld (1868) (p. 15) attributed the cause to a parasitic ichneumon fly, *Ichneumon apium mellificarium*.

Preuss (1868) (p. 15) and Schönfeld (1873-74) (p. 16) were inclined to believe that an infectious form of foul brood was due to a fungus, to which the former gave the name *Cryptococcus alvearis*.

Cheshire (1884) (p. 21) and Cheyne (1885) (p. 34) were inclined to believe that foul brood was due to a bacillus, *Bacillus alvei*.

The same disease which Cheshire and Cheyne studied came to the attention of William R. Howard in 1900 (p. 46), and he declared that the cause of it was a bacillus, to which he gave the name *Bacillus mili*.

Recent work (p. 81) has proven that American foul brood has as an exciting cause a specific bacillus, to which the name *Bacillus larvæ* has been given.

The writers of this bulletin believe that the causes for the other bee diseases have not as yet been satisfactorily demonstrated.

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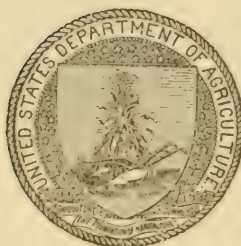
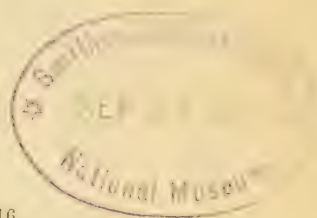
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U. S. DEPARTMENT OF AGRICULTURE,
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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON INSECTS INJURIOUS TO CITRUS
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CONTENTS AND INDEX.

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I. THE ORANGE THRIPS:

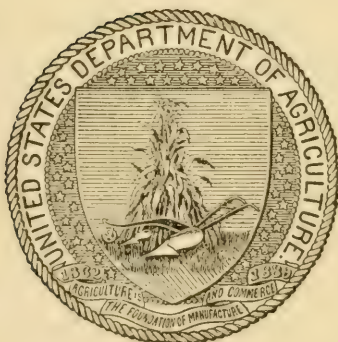
A REPORT OF PROGRESS FOR THE YEARS 1909 AND 1910.

By P. R. JONES AND J. R. HORTON,

Agents and Experts, Deciduous Fruit Insect Investigations.

II. THE RED-BANDED THRIPS.

By H. M. RUSSELL, *Entomological Assistant.*



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

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INVESTIGATIONS OF INSECTS AFFECTING TROPICAL AND SUBTROPICAL FRUITS.

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scientific assistants.

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ERRATA.

Page 17, line 4 from bottom, after *Marchal* strike out *Craw*.

Page 17, line 9 from bottom, for *Physophus* read *Physopus*.

Page 18, line 19 from bottom; page 21, line 3; page 28, lines 7 and 10 from bottom; page 29, lines 11, 13, 15, 19, 33, for *Physophus* read *Physopus*.

Page 28, lines 7 and 10 from bottom, for *rubrocinctus* read *rubrocincta*.

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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

A. L. QUAINANCE, *in charge.*

FRED JOHNSON, S. W. FOSTER, E. L. JENNE, P. R. JONES, A. G. HAMMAR, C. W.

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THE ORANGE THRIPS: A REPORT OF PROGRESS FOR THE YEARS 1909 AND 1910.

By P. R. JONES and J. R. HORTON,^a

Agents and Experts, Deciduous Fruit Insect Investigations.

INTRODUCTION.

The orange thrips (*Euthrips citri* Moulton), a small, yellow, active insect belonging to the order Thysanoptera (popularly known as thrips), scars the fruit and curls and distorts the leaves of the orange. At the present time its control constitutes the chief insect problem confronting the citrus growers of the San Joaquin Valley orange belt of California, which winds along the Sierra Nevada foothills, from east of Fresno to south of Delano. This insect, the work of which was first noticed 15 or 16 years ago, has increased in numbers with the growth of the citrus industry and recently has assumed serious economic importance.

At the urgent request of a number of orange growers of Tulare County, an investigation of the insect was begun the latter part of April, 1909. The present paper is a preliminary report of the results obtained during the seasons 1909 and 1910.

The writers wish to acknowledge the financial assistance of the Tulare County board of supervisors, the Lindsay Citrus Growers' Protective League, and the Tulare County Fruit Exchange; they desire to acknowledge the kindness of Messrs. P. M. Baier, Harry Postlethwaite, and R. H. Shoemaker in allowing the Bureau of Ento-

^a The investigation of the orange thrips by members of the force engaged in studies of deciduous-fruit insects appeared desirable, because these men were familiar with a closely related species—the pear thrips—which is very destructive to prunes, pears, cherries, etc., in the San Francisco Bay region. However, in order to keep together the articles dealing with insects damaging citrus and other subtropical fruits, the present paper is published in a series of articles dealing with insects of that class.—A. L. QUAINANCE, in Charge of Deciduous Fruit Insect Investigations.

mology the use of their orchards for experimental and demonstration purposes; and they would express their indebtedness to the large number of orange growers in Tulare County who have put into effect in their own orchards the recommendations of the Bureau, thereby demonstrating the value of the spraying treatments advised.

ORIGINAL HOME AND DISTRIBUTION.

The orange thrips is probably native to North America. Its natural habitat is probably the Sierra Nevada foothills or the adjoining plains of the southern San Joaquin Valley, and it was no doubt attracted from its natural food plants by the more succulent and luxuriant orange trees. This insect is distributed throughout the entire orange belt of the San Joaquin Valley and has been collected in several places in Southern California and at Phoenix, Ariz., by the senior author. The infestation in Arizona embraces orange groves in the Salt River Valley surrounding Phoenix, and was reported upon by Prof. J. Eliot Coit in a bulletin of the Arizona Agricultural Experiment Station.^a This gentleman, in sending specimens to Dr. W. E. Hinds for identification, probably did not obtain the true orange thrips (*Euthrips citri* Moulton), but some specimens of *Euthrips occidentalis* Pergande, which is found occasionally upon citrus trees, but which rarely causes any serious injury. The true orange thrips was described as a new species by Mr. Dudley Moulton in a bulletin of the United States Department of Agriculture, issued February 11, 1909.^b

The orange thrips has also been reported from Hermosillo, Sonora Province, Mexico, but the writers have not been able to obtain specimens from that locality.

The occasional scarring of oranges in the north-central portion of California is caused by the grain thrips (*Euthrips tritici* Fitch), and not by the orange thrips.

FOOD PLANTS.

Although the orange thrips, when described, was thought to infest only citrus trees, the writers have taken it from a number of other host plants. The following list shows the wide range of food plants upon which this insect can exist:

Of citrus fruits the following are affected: *Citrus aurantium* var. *sincensis* (Washington Navel, Australian Navel (?), Thompson Improved, Valencia Late, Mediterranean Sweet, Parson Brown, Ruby

^a Arizona Agricultural Experiment Station, Bulletin No. 58, Citrus Culture in the Arid Southwest, p. 319, 1908.

^b U. S. Department of Agriculture, Bureau of Entomology, Technical Series No. 12, Part VII.

Blood, St. Michael, Homosassa, and seedlings); *Citrus nobilis* (Satsuma and tangerines); *Citrus decumana* (grapefruit); *Citrus medica* var. *limon* (lemon); *Citrus medica* var. *acida* (lime, varieties of); and *Citrus japonica* (kumquat).

The following miscellaneous plants are infested: *Punica granatum* (pomegranate); *Vitis vinifera* (European grape, varieties of); *Schinus molle* (California pepper tree); "umbrella tree"; *Pyrus communis* (pear); *Prunus armeniaca* (apricot); *Prunus persica* (peach); *Prunus domestica* (European plum, varieties of); *Salix* sp. (willow); *Rumex* sp. (dock); *Portulaca oleracea* (purslane); *Olea europea* (olive); *Rubus idaeus* (red raspberry); *Rosa* sp. (rose); *Solanum* sp.

CHARACTER AND EXTENT OF INJURY.

Injury to citrus trees and fruit is caused directly by the feeding of both adults and larvæ upon the surface of the parts attacked. This feeding may be on the young fruit (Plate I, figs. 1, 2), the nearly mature fruit (Plate II), or the new, tender foliage (Plate III), and generally takes place on all of these. The injury to foliage is generally on young leaves, but may also occur on the axillary buds.

The manner of feeding of both the adult and larva of the thrips is identical, and consists in piercing the plant tissues with the sharp mouthparts with which both stages are equipped and then rasping the wound by a "rooting" motion of the head. The vegetable juices thus liberated from the plant cells are sucked into the alimentary canal of the insect. The characteristic marking or scabbing of the fruit, so noticeable at picking time, is started when the fruit is very small—just after the petals have fallen from the blossoms. This scabbed area is small at first, but as the fruit grows and the thrips continue to feed the markings deepen and at the same time the area of injury is enlarged. The continued feeding of a large number of thrips results in the scabbing of nearly the entire surface of the fruit. Often the marking is so large and deep over a portion of the orange that it causes the fruit to be misshapen and aborted. Frequently the entire surface is scarred while the fruit is still small, with the result that it ceases to grow and falls from the tree.

Orange trees in the Tulare County citrus belt make about four distinct growths a year, and it is on this tender foliage that the orange thrips multiply in greatest numbers. The feeding of large numbers of these little insects causes the young leaves to curl and become distorted and the whole growth to present a sickly appearance. Young trees are often held back a year or more in growth by the prompt destruction of the terminal buds soon after these make their appearance.

DESCRIPTION AND LIFE HISTORY.

THE ADULT.

The adult female of the orange thrips is a small, four-winged, orange-yellow insect, which moves very rapidly by running, leaping, and flying. The mouthparts, which are suctorial in nature, form a sharp cone projecting from the underside of the head. The adult male is smaller than the female and much more rapid in its movements.

The original description of the adult female by Moulton^a is as follows:

Euthrips citri n. sp.

Measurements: Head, length 0.75 mm., width 0.15 mm.; prothorax, length 0.09 mm., width 0.18 mm.; mesothorax, width 0.24 mm.; abdomen, width 0.25 mm.; total body length 0.86 mm. Antennae: I, 12 μ ; II, 36 μ ; III, 39 μ ; IV, 39 μ ; V, 30 μ ; VI, 34 μ ; VII, 6 μ ; VIII, 12 μ ; total, 0.205 mm. *Color*, yellow to orange-brown, with thorax and segment 2 of antennae more noticeably orange-brown.

Head twice as wide as long, retracted considerably into the prothorax, broadly rounded in front, with only slight depressions to receive the basal joints of the antennae; two spines on anterior margin, other spines not conspicuous; cheeks almost straight and parallel. *Eyes* large, occupying almost one-half the length of the head, prominent; pigment deep red to purple; facets of eyes large, eyes pilose. *Ocelli* subapproximate, margined inwardly with yellow-brown crescents. *Mouth-cone* short, reaching almost to posterior margin of prothorax, broadly rounded and with black spot at tip; maxillary palpi 3-segmented. *Antennae* 8-segmented, with segment 2 orange-yellow, other segments uniformly light brown; segments 2, 4, 5, and 6 almost equal in length; style about one-half the length of segment 6. All spines inconspicuous; sense cones transparent.

Prothorax about twice as wide as long, posterior angles broadly rounded; with long brown and outer small spine at each posterior angle, other spines not conspicuous. *Mesothorax* largest and with anterior angles broadly rounded. *Legs* light yellow-brown, with tarsi lighter but dark brown at the tip; spines on legs brown. *Wings* present and fully developed, forewings broadest near base and pointed at tips; with the ring vein and a single longitudinal vein which divides at about one-third the length of the wing from the base, the anterior part running parallel and approximate to the anterior part of the ring vein, and ending abruptly near the tip, the posterior paralleling and approaching the posterior part of the ring vein and ending about one-half the wing's length from the end, each branch with a dark-brown marking immediately at its tip. The costa bears a row of about 29 regularly placed spines. Other spines placed as follows: A group of 5 near base of median longitudinal vein; 2 on either side of where second vein branches from the first, and 3 scattered spines about equidistant on each branch vein and in each case one of these spines immediately at the end of the vein; several rather long spines on scale. Veins of the forewing unusually strong and conspicuous, somewhat orange colored near base but fading to yellow near tip. Membrane of wings transparent.

^a Loc. cit.

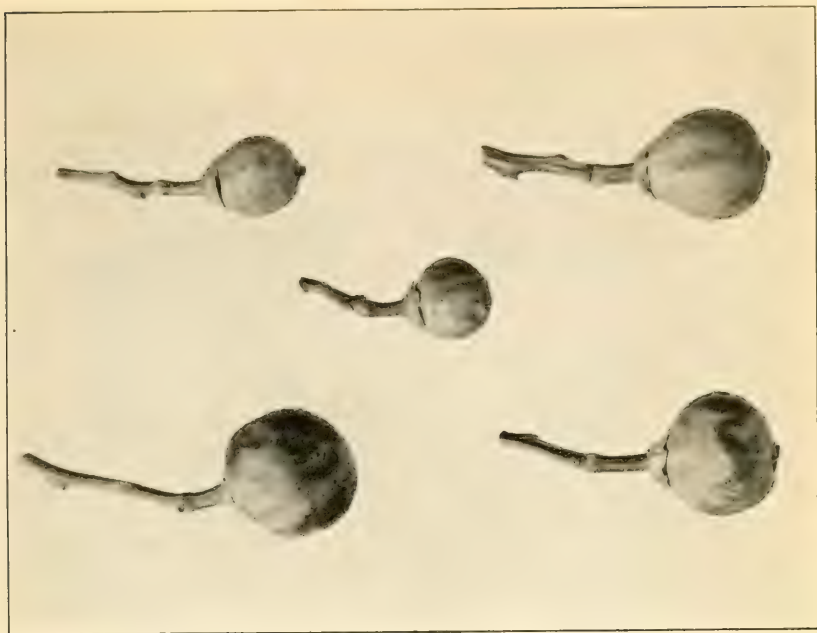


FIG. 1.—YOUNG ORANGES, SHOWING INJURY BY THE ORANGE THRIPS (*EUTHRIPS CITRI*). SOMEWHAT ENLARGED. (ORIGINAL.)



FIG. 2.—YOUNG ORANGES, SHOWING INJURY TO STEM AND BLOSSOM ENDS BY THE ORANGE THRIPS (*EUTHRIPS CITRI*). SOMEWHAT ENLARGED. (ORIGINAL.)



MATURE ORANGES, SHOWING INJURY DUE TO THE ORANGE THRIPS. (ORIGINAL.)



ORANGE FOLIAGE, SHOWING CURLED AND DISTORTED CONDITION OF LEAVES DUE TO WORK OF THE ORANGE THRIPS. (ORIGINAL.)

Abdomen ovoid, tip conical, all spines, excepting a very few at tip, inconspicuous.

Described from many female specimens collected from orange foliage and fruit at Exeter, Tulare County, Cal.

The males are similar to the females, but smaller and more active, with the orange-colored testes prominent.

THE EGG.

The egg is a bluish white, bean-shaped object measuring from 0.2 mm. in length to about 0.075 mm. in width, with a very thin shell.

THE LARVA.

First-stage larva.—Length 0.041 mm.; width of mesothorax 0.011 mm.; general shape fusiform. The antennæ, head, and legs are large and unwieldy in proportion to the rest of the body. Color translucent white. *Antennæ*, length 0.015 mm.; distinctly 4-segmented; I short, cylindrical; II more than twice as long as I, slightly urn-shaped, longer than wide; III about as long as II, obtusely fusiform; IV about as long as the other joints combined, fusiform, very finely drawn out at the distal end. Segments II, III, IV (II very obscurely) ringed, the distal rings on segment IV appearing as segmental divisions. A few fine hairs present on all segments, most numerous on IV but not very conspicuous on any of the segments. *Head* subquadrate; eyes reddish-brown. *Abdomen* gradually tapering, 10-segmented, first 8 segments subequal; IX and X large and more abruptly tapering, hairs inconspicuous. *Legs* stout, femora and tibiæ nearly equal in length, tarsi one-jointed, ending in a single claw.

Second-stage larva.—Length 0.9 mm.; head length 0.1 mm.; width 0.083 mm.; length of antennæ 0.175 mm.; width of mesothorax 0.266 mm.; width of abdomen 0.3 mm.; *Antennæ*, I, 2μ ; II, 3μ ; III, 9μ ; IV, 45μ ; V, 9μ ; VI, 15μ ; color orange-yellow. In shape similar to first-stage larva except that the abdomen is oval to ovate and generally more robust. *Head* quadrate, small in proportion to body, eyes reddish. Antennæ apparently 4-segmented under 23 objective, but under 1/6 objective distinctly 6-segmented, the chitin not extending into the fifth and sixth segments; I short, conical, about as broad as long; II cylindrical, broader than long and slightly longer than I; III obtusely spindle-shaped, about twice as long as broad and about as long as I and II combined; IV obtusely spindle-shaped but blunt on the distal end, about as long as III; V very short and thick, slightly broader than long, about one-fifth as long as IV; VI cylindrical, longer than broad, about one-third as long as IV. *Abdomen* oval to ovate, 10-segmented, the last segment tubular. *Legs* short and stout, hind femora and tibiæ about equal, hairs everywhere inconspicuous except a few under 1/6 objective, which are the most prominent on last segments of antennæ.

THE PUPA.

First-stage pupa.—Length 0.56 mm.; width of head 0.15 mm.; width of mesothorax 0.18 mm.; width of abdomen 0.25 mm.; antennæ, length 0.2 mm. Color pale translucent yellow; antennæ, legs, and wing-pads lighter. Shape similar to advanced first-stage larva; abdomen elongate ovoid. Antennæ projecting cephalad, 4-segmented; I short, thick, slightly wider than long; II obtuse, urn-shaped, about as wide as long; III obtusely spool-shaped, about as

long as I and II combined and about twice as long as wide; IV about as long as III, tapering to obtuse apex. Wing-pads extending to distal margin of the second abdominal segment, those of hind wings slightly longer. Legs stout, hind femora and tibiae about equal. Hairs present on live specimens but not prominent, short, slightly longer on tip of abdomen.

Second-stage pupa.—Length 0.666 mm.; width of head 0.133 mm.; width of prothorax 0.133 mm.; width of mesothorax 0.166 mm.; width of abdomen 0.133 mm. Shape similar to that of the adult. Color translucent white to pale yellowish; eyes reddish, more prominent than in first-stage pupa. Antennae 4-segmented, projecting backward over the head and thorax and reaching to the middle of the prothorax, second segment forming a kind of elbow from which 3 or 4 long setae project cephalad. Prothorax nearly twice as broad as long; wing-pads in pupae just entering the second pupal stage extending to the distal margin of the sixth abdominal segment; in pupae in which the adults are nearly ready to emerge the wing-pads extend to the distal margin of the ninth abdominal segment. Abdomen similar in shape to that of the adult. Legs stout, hind femora and tibiae about equal in length, setae more prominent than in first-stage pupa, longer at the tip of the abdomen; conspicuous in fresh specimens but not in mounted ones. Tip of abdomen often with a cremaster-like formation resembling in shape a fork with 4 tines. Male pupae smaller, resembling the adults, their wing-pads usually reaching past the tip of the abdomen. Setae usually not so prominent.

SEASONAL HISTORY.

The orange thrips passes the winter in the adult state, and it is generally the adult form which first becomes conspicuous upon the orange trees in the spring. Although no large number of adults has been collected in hibernation, these undoubtedly pass the winter in sheltered places, such as the dead leaves and twigs forming the trash under most orange trees; they are occasionally found on living plants and on citrus nursery stock in midwinter.

Adult thrips appear in limited numbers during March. They deposit very few eggs in the early part of April, prior to the blossoming of the Navel orange trees, but soon after most of the petals have fallen larvæ become quite numerous. Oviposition has not been observed, but it is probable that it takes place mostly at night. Examinations for eggs revealed the fact that most of them are placed in the new, tender growth, being inserted into both upper and lower leaf surfaces, and also in the shoots. They are also placed in the receptacles of the blossoms after the petals have fallen and in young fruit and fruit stems.

The larvæ are wingless and when full grown are orange colored. When ready to pupate they fall from the trees, get into a curled dead leaf, amid cobwebs, dust, and leaf particles, and hide until the transformation is completed. Pupae are not found in numbers proportionate to the larvæ and adults, since it is in this stage that the mortality rate of the insect is greatest. The pupae are very soft-bodied and less active than larvæ and adults. They move readily, however, when disturbed.

Eggs, larvæ, and adults are found on the trees, and pupæ in the dead leaves under them, from early May until early November, all four forms being present during the entire period. The broods thus overlap so closely that it is very difficult to separate them.

INTERRELATION OF ABUNDANCE OF THIRIPS AND FOOD PLANTS.

The orange thrips feed only on very tender plant tissues, namely, the young leaves, shoots, and tender fruit. This makes it necessary for them to pass from foliage to fruit and from plant to plant as the suitability of the tissues as food changes. They first make their appearance in April and May on the new growth of the Navel orange, reaching the first maximum of abundance about the time four-fifths of the petals are off. When most of the petals have fallen a few thrips pass to the more advanced fruit and the number feeding on the latter rapidly increases as the first growth of foliage becomes hardened and distasteful. The thrips continue feeding on the fruit until the latter, in turn, becomes somewhat tough, and reach a second

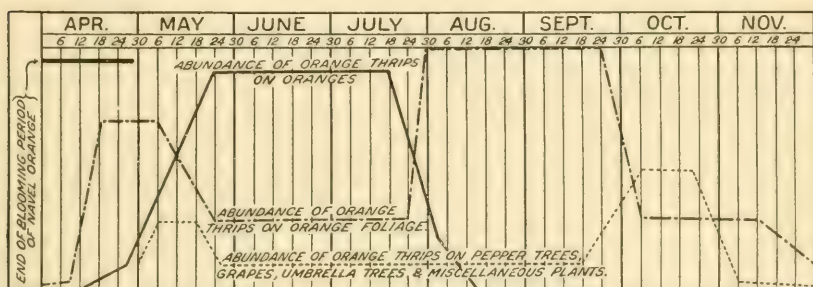


FIG. 1.—Diagram illustrating the relative abundance of orange thrips on oranges, on orange foliage, and on other plants during the season. (Original.)

and greater maximum in May, June, and July. They then pass once more to the succulent growth which has come on in the meantime, and reach the third and final maximum of concentration in August and September.

As the first citrus growths are becoming tough and before the fruit is quite tender, the thrips begin to work on the leaves of the grape, pepper tree, umbrella tree, and some uncultivated plants, reaching a minor maximum of abundance on these at the time of greatest abundance of tender leaves and stems. A second maximum of concentration is reached on some of these secondary food plants in the fall, when most all of the summer growths on citrus trees have become tough.

The relative abundance of the orange thrips on its various food plants, at different times during the season, is shown diagrammatically in the accompanying chart (fig. 1): the diagram represents the results of observations made at regular intervals in different parts of the Tulare County citrus belt.

LIFE CYCLE.

In ascertaining the length of the life cycle the average lengths of egg, larval, and pupal stages were added together, and to this an additional 3 days, which was the usual time from the appearance of the adult female until ovipositing began. The life cycle thus includes the period from egg to egg, or from the time the egg has left the abdomen of the female of one brood until the eggs of the next brood appear.

Egg stage.—The length of the egg stage was determined by confining adult thrips on potted orange plants overnight, then removing all insects and examining the plants twice daily, and counting the larvæ hatched until they cease to appear. The length of the egg stage of 19 eggs during the month of August, 1909, was found to be $2\frac{1}{2}$ days for a minimum and 8 days for a maximum, with an average of 6.2 days. Eggs deposited the latter part of September required from 20 to 24 days for incubation. During May, June, July, and August, 1910, observations on 45 eggs gave a minimum of 5 days, a maximum of 13 days, and an average of 8.1 days for 3 months. It is probable that the majority of eggs deposited during May, June, July, and August would require from 6 to 8 days for incubation, while in March, April, September, and October the length of the egg stage would be considerably more.

Larval stage.—The number of days required for the development of the larva varied from a minimum of 3 days to a maximum of 13 days, with an average of 6.06 days for 55 individuals; and a minimum of 3 days, a maximum of 13 days, and an average of 7.2 days for 73 individuals during April, May, June, July, and August. The length of the larval stage would probably be extended, similar to the egg stage, during September and October. Two distinct larval stages were observed. The first stage is usually about two-thirds as long as the second, and the larvæ more active.

Pupal stage.—The pupal stage was best observed by keeping larvæ in confinement until they pupated. The total length of the pupal instar for 30 individuals, under observation during June and July, 1909, varied from 2 to 5 days, with an average of 3.6 days; while 287 observations during April to August, 1910, gave a variation of 2 to 7 days, with an average of 4.8 days. Two pupal stages were observed, there being a distinct molt from the first to the second stage, which begins with a splitting of the skin from the head back dorsally to about 7 to 9 abdominal segments. The pupæ are more active in the first than in the second stage.

Total life cycle.—The life cycle, obtained by adding the average lengths of egg, larval, and pupal stages, and allowing 3 days

before eggs were deposited by the newly formed adults, made a total of 18.68 days for May to August, inclusive, 1909. For the months April to August, inclusive, 1910, this period was 23 days. The length of the life cycle of 8 individuals actually recorded from the egg, upon potted plants, allowing 3 days, as before, for the adults to oviposit, varied from 20 to 36 days. The data upon the 8 individuals was obtained during September and October, and the life cycle was undoubtedly longer at this time than in midsummer. The length of life of the adults observed on confined individuals was from 4 to 36 days.

Number of broods.—Although the number of generations in a season has not been definitely observed, there are probably four and a partial fifth during the period of May to July, inclusive, and one generation in each of the months March, April, August, September, and October, making in all a possibility of eight to ten generations for the season.

HABITS.

The orange thrips is very active, especially in the adult form. Its ability to run, leap, and fly is much greater than that of any other thrips so far observed by the writers. This activity and their small size allow them easily to pass unobserved. The writers have frequently seen adults fly from one tree to another 20 feet or more distant. They undoubtedly move about to a certain extent, and will go from one orchard to another in search of suitable food. Frequently they will desert the orange groves, between periodical growths, for grapes and certain deciduous fruits.

The orange thrips appear to thrive best in sunny and even very hot weather. On cool cloudy days they are less active and generally group themselves on the underside of the leaves.

Their reproductive habits are only partially understood. Males are present part of the year, but usually in more limited numbers than the females.

EXPERIMENTS WITH METHODS OF CONTROL.

CULTIVATION.

Attempts have been made to control the orange thrips, in part, by means of cultivation, but none of these endeavors has been in the least successful. One orchard was hand-raked under the trees and the soil stirred up in the fall, with the hope that pupæ would be destroyed, but results were negative. Another orchard which was plowed deeply in the fall yielded similar results.

FUMIGATION.

Some experiments have been conducted in the hope that fumigation with hydrocyanic-acid gas would prove effective in controlling the orange thrips, but all results have been unsatisfactory, because of the activity of the insects, the large number of generations, and the expense of the operation.

SPRAYING.

The only method of control which has given good results is spraying at high pressure with a contact insecticide. No sprays aside from those which kill by contact have been tried because such sprays have been unsuccessful in controlling other species of injurious thrips.

EXPERIMENTS TO DETERMINE KILLING EFFECT OF DIFFERENT SPRAYS.

The following sprays were tested in the field for killing effect on the thrips: Homemade distillate-oil emulsion, in combination with black-leaf tobacco extract, which is a dark, almost viscid liquid containing $2\frac{3}{4}$ per cent nicotine; and commercial lime-sulphur (33° Baumé) in combination with the tobacco extract. All sprays were applied with a hand pump, maintaining a pressure of 140 pounds. A large number of young fruit was examined for live and dead thrips. While this method did not give absolutely accurate results, because of the number of thrips knocked off by the force of the spray, it offered some means of comparison. Table I shows the relative killing effect of the various washes:

TABLE I.—*Killing effect of various sprays on orange thrips.*

Number of fruits examined.	Formula.	Total number of thrips counted.	Number of thrips dead.	Percentage of thrips dead.
150.....	Blackleaf 1-50 and distillate-oil emulsion 1 per cent..	129	126	97.6
200.....	Blackleaf 1-60 and distillate-oil emulsion 1 per cent..	182	170	93.4
100.....	Blackleaf 1-80 and distillate-oil emulsion 1 per cent..	67	64	92.5
Several hundred..	Blackleaf 1-85 and distillate-oil emulsion 1 per cent..	.....	.....	75
Do.....	Commercial lime sulphur 1-75 and blackleaf 1-50.....	.....	.....	90
Do.....	Commercial lime-sulphur 1-50 and blackleaf 1-100.....	.....	.....	95

EXPERIMENTS TO PREVENT MARKING OF THE FRUIT.

Experiment No. I.—A block of 150 Washington Navel orange trees was sprayed three times with distillate-oil emulsion and black-leaf tobacco extract: the former at the strength of 2 per cent and the latter in the proportions of 1 to 80 and 1 to 100 parts of spray. The spraying was tried as a means of preventing the thrips from curling the tender foliage and marking the young fruit. The first application was made May 4, 1909, after most of the petals had fallen

and when both larvæ and adults were present. The second application was made eight days later, and the third three weeks after the second, at which time the thrips began again to be numerous. All the spraying was done with a hand outfit, maintaining a pressure of 140 pounds.

In recording the results of the spray applications to ascertain their efficiency it was necessary to class the fruit, as regards injury, in four grades, as follows:

Sound: No thrips marking.

Slightly marked: A slight marking at one end or a few streaks on the surface.

Moderately marked: Both ends of fruit marked and some scabbing on the rest of the surface.

Badly marked: Nearly one-half to three-fourths of the surface marked, often with misshapen fruit.

At picking time 20 loose, or "lug," boxes of oranges from the sprayed trees and 20 from an adjoining block of unsprayed trees were counted. The results obtained are given in Table II.

TABLE II.—*Injury to sprayed and unsprayed fruit by orange thrips.*

SPRAYED.

Number of loose boxes.	Total number of oranges examined.	Number sound.	Number slightly marked.	Number moderately marked.	Number badly marked.	Per cent of sound fruit.	Per cent of slightly marked fruit.	Per cent of moderately marked fruit.	Per cent of badly marked fruit.
20	2,070	1,533	506	31	-----	74.5	24.5	1	0

UNSPRAYED.

20	2,365	337	1,047	710	271	14.5	44.5	30	11
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A commercial grading of the sprayed fruit would have placed nearly 75 per cent as "Fancy" and the remainder as "Choice," while the unsprayed fruit would have run not more than 15 per cent "Fancy" and 50 per cent "Choice," the remainder going out as "Standards" and "Culls." Of the fruit counted from the unsprayed trees, 85.5 per cent was marked, while 25.5 per cent only of that from the sprayed trees showed injury, indicating that 60 per cent of the sound fruit was due to the spraying. The thrips-marked fruit was smaller than the sound fruit, as will be seen by comparing the total number of oranges from the 20 boxes of sprayed fruit with that from the 20 boxes of unsprayed fruit. The writers have frequently noticed in the packing houses that the smaller fruit is worse marked than the larger, making it appear that the thrips injury holds back the growth of the oranges.

The sprayed block contained 121 bearing trees. These yielded 165 loose boxes of oranges. The unsprayed block contained 152 bearing trees, which yielded 162 loose boxes of oranges. The sprayed block, therefore, produced three more boxes of fruit, though containing 31 less trees, than the unsprayed block.

Experiment No. II.—A block of Washington Navel oranges embracing about 5 acres was selected in the spring of 1910 and treated three times with a spray of commercial lime-sulphur (33° Baumé), 1 part to 75 of water, combined with blackleaf tobacco extract, 1 to 150. A gasoline power sprayer was used and a pressure of 200 pounds maintained. The first application was made May 4, the second May 17, and the third June 11. The first application was timed at a date when most of the petals had fallen. The second and third applications were made when the thrips became sufficiently numerous. An effort was made to keep the young fruit free from thrips until it was the size of an English walnut, as it appeared that this would insure a high percentage of clean fruit.

Examinations and counts made of 92 loose boxes of sprayed fruit and 20 loose boxes of unsprayed fruit from an adjoining unsprayed "check" block gave the results shown in Table III.

TABLE III.—*Injury to sprayed and unsprayed fruit by orange thrips.*

SPRAYED.

Number of loose boxes.	Total number of oranges examined.	Number sound.	Number slightly marked.	Number moderately marked.	Number badly marked.	Per cent of sound fruit.	Per cent of slightly marked fruit.	Per cent of moderately marked fruit.	Per cent of badly marked fruit.
92	8,458	4,995	3,383	68	12	59	39.9	1	0

UNSPRAYED.

20	1,697	498	1,108	65	26	29.3	65.2	3.8	1.5
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The sprayed fruit shows a total of 40.9 per cent marked, while 71 per cent of the unsprayed fruit was marked, and more severely. The amount of benefit due to the spraying was 30.1 per cent, which was considerably less than in 1909, due to the fact that the thrips were more numerous and infestation worse in 1909. The total output of oranges from Tulare County in 1910 was 50 per cent freer from thrips markings than in 1909.

EXPERIMENTS WITH NURSERY TREES.

Several blocks of young nursery trees were sprayed in the fall of 1909 with commercial lime-sulphur, 1 to 75, combined with blackleaf tobacco extract, 1 to 150. By two thorough applications it was

possible to save the tender foliage and axillary buds and to promote a growth of 1 to 2 feet more on the sprayed trees than on those unsprayed.

SPRAY INJURY.

While no actual spray injury, immediate or cumulative, developed from the use of distillate-oil emulsion and blackleaf tobacco extract at the strengths indicated above, the uncertainty of this combination as compared with the lime-sulphur and blackleaf tobacco extract led to the adoption of the latter as a spray for demonstration work during the season of 1910.

RECOMMENDATIONS.

In view of the success attained in reducing injury to fruit and foliage by the orange thrips, it is believed that it will be possible to control this species in normal seasons with four applications of lime-sulphur combined with blackleaf tobacco extract.

TIME OF APPLICATION.

Three of the treatments should be made in the spring to free the fruit and spring growths of foliage from injury, since the more severe marking of fruit is done while the fruit is small. The fourth treatment should be made in August or September, according to season, for the protection of the later growths of foliage, and should be timed to catch the thrips when numerous, but before the leaves show much curling. The three spring applications should be made about as follows:

First. Just after most of the petals have fallen from the blossoms.

Second. Ten to fourteen days after the first.

Third. From three to four weeks from the time of the second treatment.

The dates for spraying in any given season must be timed by the abundance of thrips.

SPRAY DILUTIONS.

Lime-sulphur solutions should be diluted according to density. In the homemade product this may be determined by the use of a Baumé or a specific gravity spindle. The density of the commercial product will be stated by the manufacturer or may be obtained by the use of the spindle.

Lime-sulphur solution of a density of 32° Baumé should be diluted at the rate of 1 volume to 75 volumes of water; that of a density of 36° Baumé should be diluted at the rate of 1 volume to 86 volumes of water. Therefore the formula for orange-thrips spraying would be:

(1) Lime-sulphur (33° Baumé) 1 to 75 and blackleaf tobacco extract ($2\frac{3}{4}$ per cent nicotine) 1 to 100; or, using blackleaf "40" (40 per cent nicotine) tobacco extract 1 to 1,800.

(2) If lime-sulphur of 36° Baumé is used the formula would be, lime-sulphur 1 to 86 and blackleaf tobacco extract 1 to 100; or blackleaf tobacco extract "40" (40 per cent nicotine) 1 to 1,800.

To load a sprayer having a 200-gallon tank, proceed as follows: First turn water into the tank until nearly full, add $2\frac{3}{4}$ gallons lime-sulphur (33° Baumé) and 2 gallons blackleaf tobacco extract ($2\frac{3}{4}$ per cent nicotine); or 14 fluid ounces blackleaf "40" tobacco extract (40 per cent nicotine). If the lime-sulphur is 36° Baumé, use 2.1



FIG. 2.—Power spraying outfit in use in spraying for the orange thrips. (Original.)

gallons, and 2 gallons of blackleaf tobacco extract; or 14 fluid ounces of blackleaf "40" tobacco extract.

HOW TO SPRAY.

In spraying for the orange thrips only those insects actually hit with the spray will be killed. As this insect obtains its food by sucking the plant juices, stomach poisons are of no avail. In order to spray with greatest efficiency it is necessary to use a gasoline power sprayer, maintaining a pressure of 180 to 200 pounds. (See fig. 2, showing a power outfit in operation.) Angles or elbows should be used on all spray rods so that "overshot" and "undershot" spraying can be done; that is, spraying from above downward, and from below up-

ward to reach the lower surface of the leaves. The trees should be drenched until they drip freely.

Especial care should be taken with the outside fruit as the thrips scar this badly, but cause little or no injury to inside fruit.

Either chamber nozzles of the Cyclone type or Bordeaux nozzles may be used. If the former are used, disks with holes of about $\frac{3}{4}$ inch diameter will be best. Double nozzles can be used to advantage on large trees, and will save time. It is preferable to use two lines of hose as this will insure more thorough work than where four leads are used. A majority of orange growers fail to apply a sufficient number of gallons of spray per tree. The following table will show approximately the correct amount to apply, and will enable those intending to spray to estimate the quantity of spray material needed for the season:

TABLE IV.—Quantities of liquid required in spraying for orange thrips.

Age of trees.	One application.		Total gallons of diluted spray per acre of 100 trees, 4 applications.
	Gallons diluted spray per tree.	Gallons per acre of 100 trees.	
Years.			
2-3.....	2	200	800
5-7.....	4	400	1,600
8-10....	5	500	2,000
12-14...	8	800	3,200

SUMMARY.

The orange thrips, a minute, orange-yellow insect of the order Thysanoptera, curls the leaves and scars the fruit of citrus trees in the San Joaquin Valley of California, the southern California orange belt, and the Salt River Valley of Arizona.

Although this insect has been known by its work for some fifteen or sixteen years it has but recently been described, and it has now become of serious economic importance in the orange belt of the San Joaquin Valley of California.

The orange thrips has numerous generations yearly, its life cycle requiring approximately 20 days, and it is to be found upon the orange trees from March to November.

It can be controlled by four sprayings of lime-sulphur solution combined with a commercial tobacco extract, which should be applied when the thrips become sufficiently numerous. Three applications should be made in the spring months to save the fruit and spring

growths from injury, and one in the fall to lessen the feeding injury to the fall growth of the orange trees.

From two to eight gallons of this combination spray should be applied per tree, at a high pressure, and in a very thorough manner, as only thrips that are hit will be killed.

Experiments in spraying have shown that three thorough applications at the proper times have resulted in from 20 per cent to 60 per cent more "fancy" fruit in the sprayed as compared with the unsprayed blocks.



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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON INSECTS INJURIOUS TO CITRUS
AND OTHER SUBTROPICAL FRUITS.

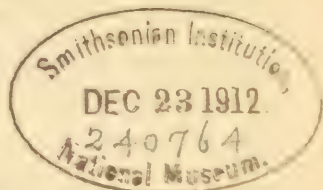
THE RED-BANDED THRIPS.

BY

H. M. RUSSELL,

Entomological Assistant.

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II

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PAPERS ON INSECTS INJURIOUS TO CITRUS AND OTHER SUBTROPICAL FRUITS.

THE RED-BANDED THRIPS.

(Heliothrips rubrocinctus Giard.)By H. M. RUSSELL,
Entomological Assistant.

INTRODUCTION.

For a period of about twelve years the red-banded thrips (*Heliothrips rubrocinctus* Giard) (Pl. V) has ranked as an important insect enemy of the cacao in the West Indies, where it is known as the "cacao thrips."^a Recently it has obtained a foothold in Florida, where at the present time it occurs at several widely separated localities adjacent to the East Coast, attacking principally the mango and avocado. The list of food plants of this insect embraces a number of different species, and as the cacao, from which its tropical name, the cacao thrips, is derived, is not at present grown to any extent in the United States, the writer has called it the red-banded thrips, one of the most noticeable characteristics of the species being the bright-red cross-band which in all stages decorates the middle of the body.

The writer, when stationed at Miami, Fla., during 1909, made a few observations on this species, and it has seemed best to publish them in this preliminary account, in order that growers may be prepared to combat this new enemy, which has already caused great damage in certain islands of the West Indies, and which will, if neglected, undoubtedly prove a serious pest in this country. It is hoped that this paper may serve also to keep the growers of California on their guard, since the introduction of this thrips might result injuriously to the culture of the guava and avocado in that State.

HISTORY.

This thrips was first described as *Physophus rubrocineta* by August Giard^{3b}, in 1901, from specimens received from Guadeloupe, French

^a Mr. Charles S. Banks in 1904, in Bul. No. 1, Entomological Division of the Bureau of Government Laboratories of the Philippines, page 30 and figs. 32 and 33, reports a black thrips as injuring cacao. This thrips, however, as shown by his figure, belongs to the suborder Tubulifera and resembles in its injury *Mesothrips fuscum* Marchal Craw., which causes injury to various species of Ficus in Key West, Cuba, and Porto Rico. Where the leaves of these plants are attacked by this insect they curl up and the insect hides within in great numbers.

^b See Bibliography, p. 28.

West Indies, where it had been the cause of considerable damage to the cacao. Giard published some account of its damages and stated that it was the same species that Maxwell-Lefroy² had recently reported as injuring cacao in the island of Grenada. In this report Maxwell-Lefroy considered the conditions then existing in Grenada and gave an account of the spraying experiments against this insect. Probably the first mention of this insect was that of W. E. Broadway,¹ in 1898, when attention was called to the "blight" of the cacao.

A. Elot,⁴ in 1901, gave a very clear account of the injury caused by this insect and of its habits and republished the description of Giard. According to this writer the different stages fed on the foliage and pods of the cacao and caused damage not only by destroying the leaves but by so changing the appearance of affected pods that it was impossible to distinguish them from the mature pods; thus great damage resulted from picking the pods prematurely.

In 1902 an editorial review⁵ of this article by Elot appeared in a West Indian Bulletin, and also one by W. Fawcett⁶ on the work of Maxwell-Lefroy appeared in a bulletin of the botanical department of Jamaica. During 1903 and 1904 several short articles were published, and these are given in the bibliography.

In 1905 A. Elot¹³ published another article on the injury to cacao by this thrips. In this he repeated a good part of the information used in his former article. He stated that cultivation, pruning and fertilizing would be very beneficial to trees attacked by this insect.

The next year H. A. Ballou¹⁴ published a short article on *Physoptus rubrocincta*, which was largely abstracted from the earlier one of Maxwell-Lefroy. This same writer between 1906 and 1909 published a number of short articles that are listed in the bibliography.

Mr. H. J. Franklin,¹⁸ in 1908, published an article in which he redescribed the female and also described the male for the first time. He recorded it as feeding on cacao and kola in St. Vincent Island, and also published a bibliography of the species.

In 1909²⁰ Maxwell-Lefroy reported that it occurred in Ceylon, and that it was probably introduced into the West Indies from there.

F. W. Ulrich,²¹ in 1910, reported a serious outbreak during November and December in the island of Trinidad. The same author,²⁴ in February, 1911, published a bulletin on this insect. He gave very good colored plates showing the adult, larva, and pupa, and the appearance of injured leaves and pods of the cacao. The different stages and habits were described and the life history studied to some extent for the island of Trinidad. Ulrich recorded it as feeding on the cacao, guava, roses, almond, and mango.

J. E. Higgins,²⁵ in 1911, recorded it as injuring mango seedlings in the greenhouses at the Hawaii Agricultural Experiment Station.

This account of the history of the red-banded thrips takes up only the more important notices that this insect has received. For further information see the bibliography (p. 28) or the article by Ulrich ²⁴ published in 1911.

RECENT RECORDS.

On March 28, 1900, specimens of the larva, pupa, and adult of this insect were received by this bureau from Mr. D. Morris, of Barbados Island. He stated that they were collected in Dominica on cacao. On October 5, 1900, another lot, from Grenada, British West Indies, was received from Mr. Morris. Mr. P. J. Wester, formerly of the Bureau of Plant Industry, during the winter of 1908 sent to the Bureau of Entomology, from Miami, Fla., several lots of mango leaves badly injured by *Heliothrips rubrocinctus* Giard and *Heliothrips hæmorrhoidalis* Bouché, working together. He wrote that previous to that time they had not seemed to cause much damage. The writer, during January and February, 1909, found these two insects at Miami, Fla., working together in large numbers on the leaves of the mango and the avocado. Mr. Edward Simmonds, on November 1, 1911, sent a number of mango leaves from Miami, Fla., that were quite badly infested.

August 6, 1912, Mr. H. L. Sanford collected specimens of the adult, larva, and pupa, in the greenhouses of the Department of Agriculture, at Washington, D. C. The insects were seriously attacking mango plants received from the island of Mauritius.

NATURE AND EXTENT OF INJURY.

Injury by the red-banded thrips is similar to that of the greenhouse thrips (*Heliothrips hæmorrhoidalis* Bouché)^a and of the bean thrips (*Heliothrips fasciatus* Pergande),^b and is likewise caused by the manner in which these insects obtain their food. The present thrips is treated here as an enemy to the mango and avocado (alligator pear) only, as cacao is not at present of importance as a crop in this country. The adults and larvæ feed together on the same foliage and injure this in the same way. The epidermis is first pierced by the sharp mouthparts and then the leaf tissue within is rasped or scraped out, leaving a minute spot where the chlorophyll or green content of the leaf has been removed. This spot becomes brown. These spots become very abundant and after a while run together, forming large brown patches near the main or side veins, the leaves later turning brown and drying up. In severe cases the entire leaf surface is

^a For description of injury by the greenhouse thrips see Bul. 64, Pt. VI, Bur. Ent., U. S. Dept. Agr., p. 44, 1909; also Cir. 151, Bur. Ent., U. S. Dept. Agr., 1912.

^b For description of injury by the bean thrips see Bul. 118, Bur. Ent., U. S. Dept. Agr., 1912.

infested, and in such cases the larvæ move around to the other side and feed. Thus the function of the leaf is entirely destroyed and the leaves dry up and often fall. (See Pl. IV.) In feeding, this thrips excretes over the surface of the infested leaves a reddish fluid in small spots, which hardens and turns black. Although it has not been observed on the fruit, it is probable that in cases of severe attack this insect will also attack the fruit of the mango and avocado in the same manner that it does the pods of cacao. If such a condition should result, it will produce even greater loss, since the value of these high-grade fruits will be greatly reduced. The effect of the feeding is graphically shown in Plate IV, where the leaf on the left is uninjured and the leaf on the right has been infested by thrips.

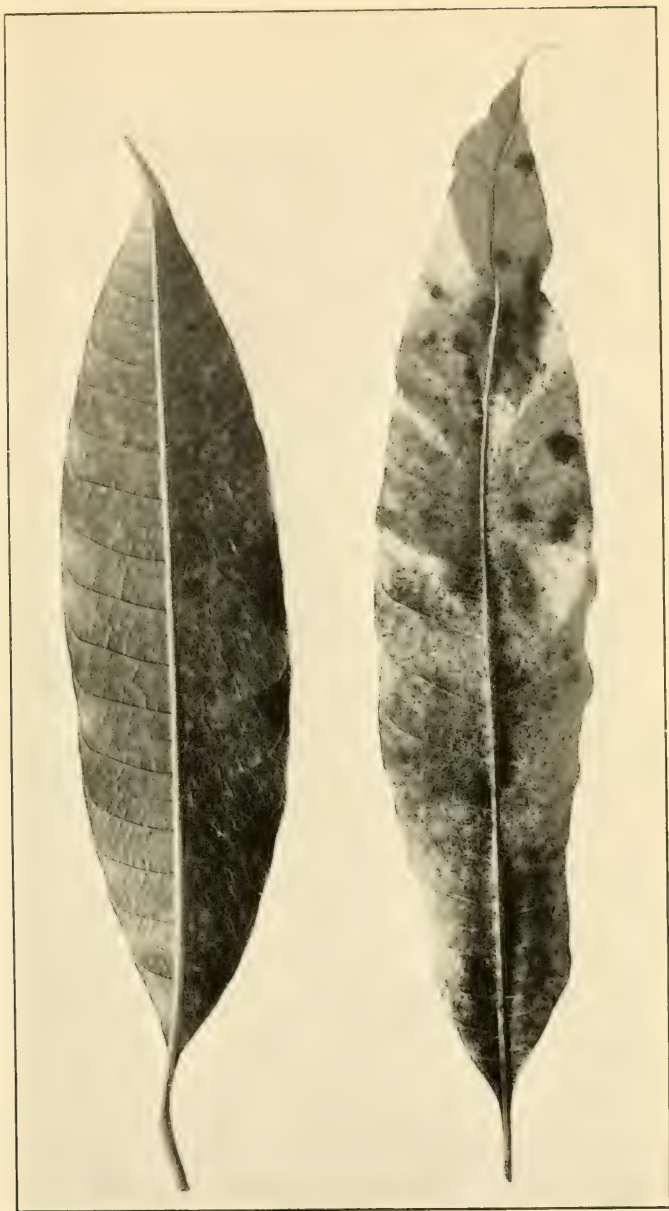
ORIGIN AND DISTRIBUTION.

Heliothrips rubrocinetus was originally described from specimens collected in the island of Guadeloupe, French West Indies. At about the same time it was observed to be injuring cacao on islands of the British West Indies—Grenada, St. Vincent, St. Lucia, and Dominica. Maxwell-Lefroy, in *Indian Insect Life*, wrote: "*Physophus rubrocincta* Chard is a serious pest to cacao in the West Indies, to which place it was probably introduced from Ceylon." There has been some question as to whether the thrips which injures cacao in Ceylon is this same species, but as the author quoted above was one of the first to study this species in Grenada it is hardly probable that he would mistake another insect for it, provided he saw the insect in Ceylon that he refers to this species.

This thrips occurs also in Trinidad, the island of Tobago, the Virgin Islands, and the Uganda, and within the past year has been recorded from the Hawaii Experiment Station greenhouses in Honolulu.

In the United States it is confined to a short strip of the Florida east coast centering in Miami. As it is a tropical species, it will probably not spread north of Florida; therefore, unless it obtains an entrance into California or into greenhouses in the North the distribution in our own country will be limited. This insect has been taken in one of the greenhouses of the Department of Agriculture on plants from Mauritius. At present it is quite widely distributed in the tropical islands of the Atlantic and Pacific Oceans, and its original home was, without a doubt, in some of these islands. It may have first come from Ceylon, as Maxwell-Lefroy suggests, or its original home may be in the West Indies. Its habitat is the Tropical Life Zone, as designated by Dr. C. Hart Merriam.^a

^a Life Zones and Crop Zones of the United States. Bul. 10, Biol. Surv., U. S. Dept. Agr., 1898.



LEAVES OF THE MANGO (*MANGIFERA INDICA*), SHOWING INJURY BY
THE RED-BANDED THIRPS (*HELIOTHIRPS RUBROCINCTUS*).

The leaf on the right is badly injured by the feeding of the thrips, while
the leaf on the left is uninjured. (Original.)

CLASSIFICATION.

When first described this insect was put in the genus *Physophus* and remained there until 1908, when Franklin placed it in the genus *Heliothrips* because of its structure. II. Karny^a, in a revision of the genus *Heliothrips*, made this species the type for a new subgenus, *Scienothrips*. However, for the present, the writer prefers to refer it to the genus *Heliothrips* in its old sense. This species is readily placed in this genus by reason of the downward curved ovipositor, the reticulated structure of the body, and the 8-segmented antennæ with segment 8 longer than 7, and the spines on the wings pointed.

DESCRIPTION.

THE ADULT.

(Pl. V, fig. 1.)

As an adult this insect can be separated from others associating with it by the characters given above and by the black body, dark wings, the reddish band, evident in the first three segments of the abdomen, and the red color of the anal segment. The adult female (Pl. V, fig. 1) is about one twenty-fourth of an inch long (1.1174 mm.) and quite stout. The color is dark brown or black.^b The male is much smaller and is apparently not very commonly collected. When the adults first emerge, the colors of the body are light, but in a short time these darken and the mature colors appear.

THE EGG.

The egg was not observed by the writer, but was described by F. W. Urich,²⁴ as follows:

As dissected out of the female the egg is kidney-shaped, 0.255 mm. long and 0.105 mm. wide, with a very thin shell and transparent.

The eggs are inserted by the female into the tissues of the mango or avocado leaves and in the case of the cacao, as observed by Urich, in the leaves and pods of the bean as well.

THE FIRST-STAGE LARVA.

The following description was made while the larva was less than a day old and before it had begun to feed:

Length about 0.25 mm. and nearly six times as long as wide. General shape fusiform; head, antennæ, and legs very large in proportion. Head quadrate, rounded in front, light yellow in color; ocelli absent, eyes red, antennæ seven-jointed, hyaline; legs and body hyaline; segments 1 and 2 of abdomen crossed by a bright red band, anal segment red; end of abdomen with four long hairs about four times as long as segment 10.

^a Ent. Rundschau, Jahrg. 28, pp. 179-181, December, 1911.

^b For full description of this species see Franklin's paper, ¹⁸ pp. 719-723

THE SECOND-STAGE OR MATURE LARVA.

(Pl. V, fig. 2.)

Length 1.0117 mm.; width of mesothorax 0.2718 mm. Body long and cylindrical, the head and thorax considerably narrowed, and the abdomen gradually converging to the end. Color of thorax and abdomen translucent white to orange-yellowish. Contents of the alimentary tract showing through as a greenish mass extending from the mesothorax to the fifth abdominal segment; the posterior half of segment 1 and all of segments 2 and 3 of the abdomen bright red; last segment of the abdomen also bright red. Surface of the body covered with minute granules and with numerous short setae which are black in color and swollen at the tips. Head 0.0906 mm. in length, 0.1559 mm. in width, front rounded and sides bulging considerably, constricted behind the eyes to a distinct neck. Eyes made up of a few large facets, red, no ocelli present. Antennae seven-segmented, about 0.3473 mm. long; segments 3 and 4 long, slender, spindle-shaped, and annulated; 5 short, cylindrical; 6 longer than 5, slender, cylindrical; 7 slightly longer than 6, very slender; near the distal end of each segment are a number of setae. Prothorax with the anterior margin considerably narrower than the posterior, sides rounded, a pair of setae on each side, a pair on dorsum near anterior margin, and another pair near posterior margin. Mesothorax and metathorax with a number of setae near sides and a pair of spiracles on the anterior mesothoracic angles. Legs translucent white. Abdomen 0.6795 mm. in length, 0.3473 mm. in width, fusiform, no evidence of ovipositor in female larva, a pair of spiracles on the sides of segments 2 and 9; segments 9 and 10 about equal in length, 10 with four long, stout setae, 0.2265 mm. in length. Segments of abdomen bearing longitudinal rows of setae at sides, just within outline, and two incomplete rows on the dorsum.

THE YOUNG NYMPH OR PREPUA.

(Pl. V, fig. 3.)

Length 1.087 mm.; width of mesothorax 0.2567 mm. Shape fusiform, similar to that of the adult. Head length 0.1057 mm.; width at the eyes 0.1812 mm. Head rounded in front and on angles so that the sides bulge strongly, sides strongly converging to posterior margin. Head translucent white, more or less blotched with orange; eyes red or orange, not large; ocelli absent; a pair of setae behind the eyes, another pair between the eyes, and a third pair back of pair 2 more widely separated. Antennae 7-segmented, translucent white, except segment 1, which is orange, extending forward about twice the length of the head; segment 1 cylindrical, broader than long; segment 2 cylindrical, narrowed at distal end, about twice as long as 1 and not so broad; 3 about as long as 2, more slender, base constricted; 4 shorter than 3, somewhat rounded and constricted at the base; 5 as long as 3 and 4 together, slender cylindrical; 6 short cylindrical and not as stout as 5; 7 cylindrical, longer than 6, and tapering at the tip; a few setae present on the segments. Prothorax more than twice as wide as long; sides rounded, with the posterior margin the widest; translucent white, marked with orange; three setae on each side, that at posterior angle longest, and four setae in a transverse row on the dorsum near the anterior margin. Mesothorax with prominent angles, translucent white, with some orange on the dorsum. Wing cases translucent white, distinct from each other; those of the fore-wing extending to the posterior edge of segment 2 of the abdomen, and those of the hind wings extending to beyond anterior edge of segment 3. Legs translucent white to faint yellow, strong, with a number of white setae. Abdomen fusiform like that of the adult, translucent white to yellowish orange, with a bright red band on posterior half of segment 1 and on all of segments 2 and 3 (in some examples, dashes of red on side of 2 or segments following), last segment also bright red. Abdomen with about six longitudinal rows of white setae increasing in length toward the posterior end of the body. Length of the abdomen 0.6644 mm.; width 0.2869 mm.

THE FULL-GROWN NYMPH OR PUPA.

(Pl. V, fig. 4.)

Length 1.047 mm.; width at mesothoracic angles 0.2567 mm.; shape similar to adult. Color translucent white to yellowish orange, first three segments and last segment of the abdomen bright red. Head 0.1208 mm. in length, 0.1963 mm. in width; white, with more or less orange (in older pupæ surface distinctly reticulated); eyes oval, dark red, larger than in prepupal stage, facets large; three ocelli present in close triangle between the eyes in older pupæ, white, surrounded by orange. Antennæ laid backward on head and reaching to beyond anterior edge of mesothorax; segments indistinct, transparent white; segments 1 and 2 projecting more or less forward and upward; on segment 2 a long slender seta, 0.1208 mm. in length, projecting forward.

Thorax (very plainly reticulated in older pupæ) translucent white, with some yellowish orange on mid-dorsal region. Prothorax 0.1057 mm. in length, 0.2114 mm. in width, sides rounded. The entire body well supplied with setæ, those on posterior angles of prothorax, on wing-cases, and on sides of the abdomen quite long. Wing-cases 0.4934 mm. in length, extending to beyond anterior margin of segment 6 of the abdomen, translucent white to faint yellow. Length from head to end of wing-pads 0.755 mm. Legs translucent white, very plainly reticulated in older pupæ. Abdomen fusiform, surface reticulated in older pupæ, general color translucent white to yellow with the first three segments and the last bright red; in some examples a patch of bright green was observed, caused by food in the alimentary canal. Length of abdomen 0.5889 mm.; width 0.302 mm.; length of posterior setæ 0.906 mm.

HABITS OF THE ADULT.

The adults are found feeding on both the surface and underside of the foliage. In many cases they are to be found mingling on the same leaf with *Heliothrips hæmorrhoidalis* Bouché. The adults also are found feeding in a colony with the pupæ and larvæ, all in close proximity to each other. They feed on the leaf content as do other thrips, and in many cases rest alongside the leaf vein or under the webs of the red spider. If disturbed or alarmed these insects were observed to make long quick jumps or to crawl rapidly over the leaf much faster than *Heliothrips hæmorrhoidalis* ever moves. There is another peculiar trait possessed by members of this species, namely, that the adults are often observed crawling on a leaf with the abdomen lifted and curved forward over the body. They are apparently very sensitive to cold, as adults that were placed on a cake of ice became motionless at once, but began to move actively again within a short time after removal.

This species, like *H. hæmorrhoidalis*, selects the tender young foliage to feed upon, and while doing so the female deposits the eggs in the leaf. After the female has deposited each egg she seals the opening with a large drop of excrement which dries to a flat scale so that the egg-pocket is concealed. As these leaves begin to become exhausted from the excessive feeding of the adults and larvæ that have hatched, the adults forsake them and attack the newer leaves of the plant. While this insect was under the observation of the writer, flight

was never observed, but Ulrich²⁴ observed it in flight in the cool of the evening. The writer has never observed the male and it seems to be quite rare, as Ulrich observed it on only a few occasions. Reproduction for portions of the year is parthenogenetic, but at other times bisexual. The adults seem to be very sensitive to lack of moisture and die rapidly in breeding vials. On mango trees in the greenhouse individuals have been observed to live as adults for from 14 to 17 days, when, although still very active, they were lost. Probably this adult has a more extended period of life as the author has kept specimens of a related species, *Heliothrips fasciatus*, alive for three months.

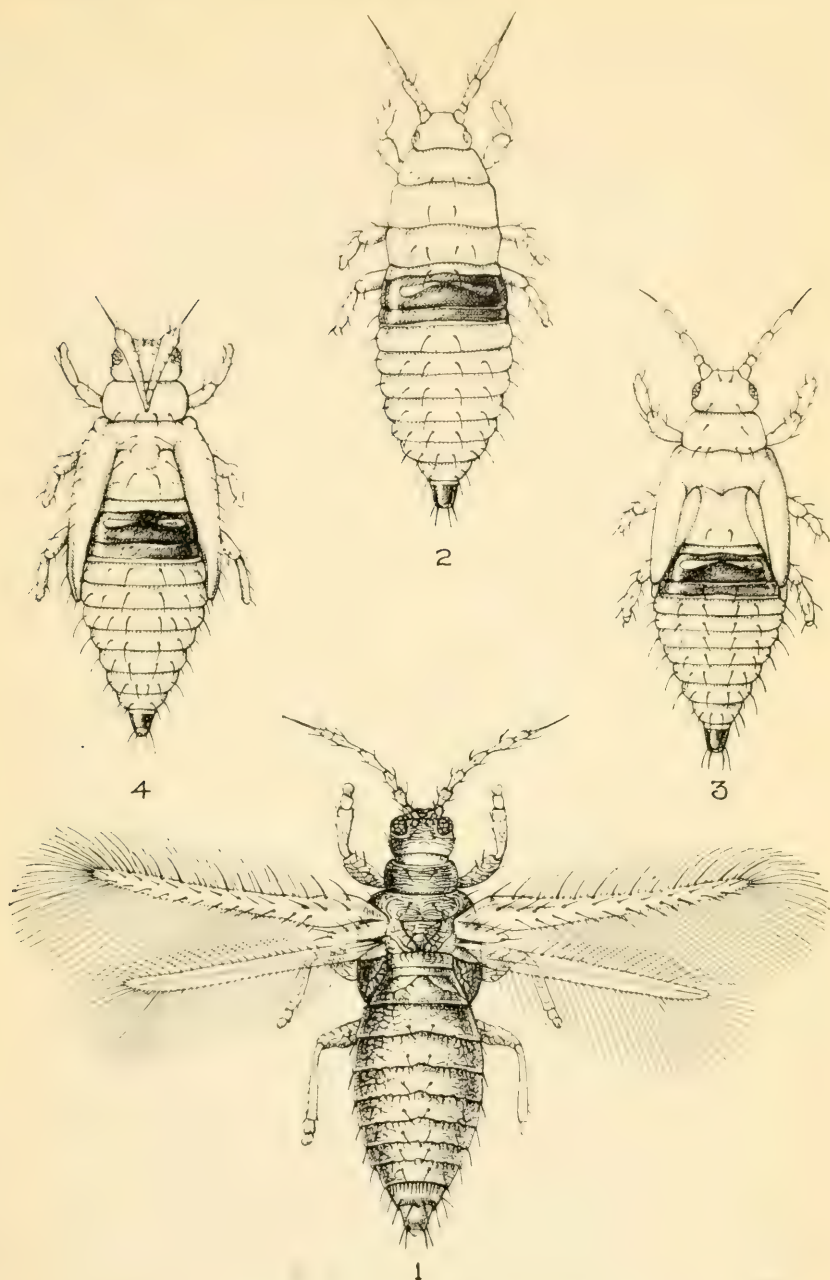
HATCHING OF THE EGG.

The eggs, as they near the end of the period of incubation, become considerably swollen, so that if the scale covering each egg is removed there is a slight elevation of the leaf noted. The larva hatches by the same process as that used by *Heliothrips hæmorrhoidalis*, but emerges from under the dried scale at one side, and in many cases, as it moves away, carries this scale on its back.

HABITS OF THE LARVA.

The larvæ feed on the leaves in company with the adults and generally prefer the underside, but the writer has frequently observed them in large numbers on both sides of the leaf. They feed clustered together in colonies, in folds of the leaf, or along the main vein, or even under red-spider webs. As they feed, the leaf becomes full of minute brown spots where the chlorophyll has been extracted, and in severe cases these run together and the entire leaf becomes brown and dried up. At all times the larva holds the tip of the abdomen in the air and bears a drop of reddish liquid, which is held more or less in place by the stout anal hairs. As this increases in size it falls to the leaf and the surface becomes covered with drops of excrement, as occurs with plants affected by *Heliothrips hæmorrhoidalis*. The larvæ when disturbed crawl rapidly away, or, if exposed to the light, endeavor to reach the shade again. In some cases the molted skin was observed being carried on the tip of the abdomen, but this may have been accidental.

The larvæ when full grown cluster in a fold of the leaf, near the midrib or under the web of a red spider, to change to prepupæ. The skin at the head then splits and gradually, by contractions of the body, the prepupæ work their way out. When they have emerged they leave the empty skins on the leaf, or in some cases carry them around on the end of the abdomen.



THE RED-BANDED THRIPS (*HELIOTHRIPS RUBROCINCTUS*).

Fig. 1.—Adult female. Fig. 2.—Full-grown larva. Fig. 3.—Prepupa. Fig. 4.—Pupa. (Original.)

HABITS OF THE PREPUPA AND PUPA.

The prepupæ remain clustered so closely that they almost touch each other and are almost motionless. However, if alarmed or disturbed they move rapidly away. At all times they carry the antennæ, which are freely motile, out in front of the head. The prepupæ change to the pupæ in among the colony of prepupæ and larvæ on the leaf. When the prepupa is ready to molt, the skin is ruptured over the head and gradually worked off at the posterior end by contractions of the body, and the cast skin is left behind on the leaf.

The pupæ, while they possess the power of motion, are more sluggish, and will not move around unless disturbed or exposed to a strong light. They carry the antennæ folded back over the head onto the prothorax. In recently formed pupæ the reticulations on the body are absent, as also are the ocelli; but as the pupæ develop, the ocelli gradually appear between the eyes and the reticulations gradually become evident, until they are extremely heavy and distinct. As the pupæ become nearly mature, the body begins to turn darker, until just before emergence of the adults the pupæ are almost black. The adults emerge from the pupæ in the same manner that the younger stages molt; they then move away for a short distance and remain more or less motionless until the chitin hardens. Within a day the full colors have developed and the adults begin feeding.

FOOD PLANTS.

In Florida this insect has been found feeding on the avocado (*Persca gratissima*) and mango (*Mangifera indica*), causing serious injury to these plants.

Maxwell-Lefroy recorded it on cashew, guava (*Psidium guajava*), cacao (*Theobroma cacao*), and Liberian coffee (*Coffea liberica*), and Ballou recorded it on the wild guava (*Anacardium occidentale*) and cotton. Urich recorded it as feeding on the cashew, cacao, guava, roses, the Mexican almond or umbrella tree (*Terminalia catappa*), and mango. Franklin also recorded its occurrence on the cacao and kola (*Sterculia acuminata*).

LIFE CYCLE.

The writer has worked out the complete life cycle of this insect in the greenhouse at Washington, but for lack of time failed to follow it through successfully while in the field at Miami. In the greenhouse the egg required from 15 to 16 days for incubation, with an average mean temperature of 77° to 78°. (See Table I.)

TABLE I.—Length of the egg stage of *Heliothrips rubrocinctus*, Washington, D. C., 1912.

Experiment No.	Date of oviposition.	Eggs hatched on—	Minimum length of stage.	Maximum length of stage.	Average mean temperature.
1.....	Apr. 11	Apr. 26 (1).....	Days. 15	Days.	° F. 78.78
2.....	Apr. 14	{ Apr. 29 (2)..... Apr. 30 (1).....	15	16	77.1

From leaves picked in Florida on April 3 the larvæ continued to emerge until April 12, giving a minimum length in this case at Miami of at least nine days.

The length of the egg stage was not determined by the writer for Florida. Urich found that on the island of Trinidad the eggs hatched for three days after they were picked and freed of the adults, but made no exact determination on the length of incubation. The length of the egg stage in Florida will be very similar to that of *hæmorrhoidalis*, or from 8 days as a minimum to 16 or 17 days as a maximum as observed by the writer in the greenhouse.

In the greenhouse a number of experiments were conducted and gave a length of the larval stage of from 8 to 16 days, with average mean temperatures of 68° to 76° F. (See Table II.)

TABLE II.—Length of larval stage of *Heliothrips rubrocinctus* in greenhouse, Washington, D. C., 1912.

Experiment No.	Date larvæ hatched.	Number hatched.	Date first larva pupated.	Date last larva pupated.	Number pupated.	Minimum length of stage.	Maximum length of stage.	Average mean temperature.
1	Apr. 3	28	Apr. 11	Apr. 18	20	Days. 8	15	68.88
2	do.....	10	do.....	Apr. 13	6	8	10	76.08
3	Apr. 6	6	Apr. 17	Apr. 22	3	11	16	68.5

¹ Records missing for first four days, but would probably not alter the average mean temperature more than a degree either way.

In Trinidad the larval period requires six days for development. The temperatures were not stated, but were probably quite high, as the growth was very rapid. In Florida the larval period will probably occupy from 6 to 20 days, depending upon the temperature and humidity.

Urich found that the prepupal stage required one day and the pupal stage two days for development. During the month of November, with a moderately cool temperature, in a greenhouse, the writer found that the prepupal stage required from one to two days and the pupal stage from two to six days.

A large number of prepupæ, under observation in the greenhouse in April, 1912, were found to require from one to four days for devel-

opment before changing to pupæ, with an average mean temperature of about 71° F. (See Table III.)

TABLE III.—Length of prepupal stage of *Heliothrips rubrocinetus* in greenhouse at Washington, D. C., April, 1912.

Experiment No.	Date larva changed to prepupa.	Number changed to prepupa.	Date prepupa changed to pupa.	Number changed to pupa.	Minimum length of stage.	Maximum length of stage.	Average mean temperature.
					Days.	Days.	° F.
1	Apr. 11	2	Apr. 12	2			71.5
	Apr. 13	1	Apr. 15	1	1	2	
2	Apr. 12	1	Apr. 16	3	3	4	72.35
	Apr. 13	2					
3	Apr. 11	5	Apr. 13	3			
	Apr. 12	2	Apr. 14	3			
	Apr. 15	6	Apr. 16	5	1	2	70.75
	Apr. 16	3	Apr. 18	2			
4	Apr. 17		Apr. 20	1	3		1.68
	Apr. 20		Apr. 23	1			

¹ Approximate.

A number of pupæ in the greenhouse required from four to seven days for development, with an average mean temperature of from 68° to 70° F.

TABLE IV.—Length of pupal stage of *Heliothrips rubrocinetus* in greenhouse at Washington, D. C., April, 1912.

Experiment No.	Date prepupa changed to pupa.	Number changed to pupa.	Date pupa changed to adult.	Number changed to adult.	Minimum length of stage.	Maximum length of stage.	Average mean temperature.
					Days.	Days.	° F.
1	Apr. 12	2	Apr. 16 ¹	1			
			Apr. 16 ²	1			
	Apr. 13	3	Apr. 17	2	4	5	70.75
			Apr. 18	1			
2	Apr. 13	3	Apr. 19	1			68.5
			Apr. 20	2			
	Apr. 15	3	Apr. 20	1	4	6	68.57
			Apr. 20	2			
	Apr. 22	2	Apr. 27	1			69.37
3	Apr. 20	1	Apr. 24	1	4		69.75
4	Apr. 16	3	Apr. 21	2	6	7	67.5
			Apr. 22	1			

¹ 9 a. m.

² 1 p. m.

In Trinidad this thrips requires 12 days from the time the egg hatches until the adult appears, and with an estimated period of 4 to 6 days for the egg stage the life cycle will be approximately 16 to 18 days. Observations in a greenhouse at Washington, D. C., gave a total life cycle of 28 days as a minimum to 43 days as a maximum, with an average mean temperature of about 70° F. In Florida the life cycle may require only 20 days as a minimum, but during parts of the year at least will require in some cases 43 days for the complete life cycle and possibly even longer. This insect will probably have at least 10 generations annually in Florida.

NATURAL CONTROL.

Rains.—The heavy summer rains that occur in Florida are directly responsible for the destruction of large numbers of this thrips.

The author did not observe any natural enemies feeding on this thrips. However, as *Triphleps insidiosus* Say feeds quite commonly on *Heliethrips fasciatus* in California, it will probably be found to attack the present species.

ARTIFICIAL CONTROL.

Where this insect becomes sufficiently abundant to cause injury to the mango and avocado, it can be controlled by careful spraying with a nicotine extract. Mr. Edward Simmons, at the subtropical gardens of the Bureau of Plant Industry, has controlled it during the last two years by spraying according to the following formula:

Blackleaf tobacco extract.....	gallon..	1
Whale-oil soap.....	pound..	1
Water.....	gallons..	50

First dissolve the soap in a quantity of water, then add the blackleaf tobacco extract and full amount of water and thoroughly mix. This spray should be applied to the trees at a good pressure, so as to thoroughly coat the surface and underside of the leaves.

Another formula that will give equally good results is the following: Take 1 part of blackleaf tobacco extract containing 40 per cent nicotine solution to 1,500 to 2,000 parts of water and add 1 pound of whale-oil soap to every 50 gallons of the mixture and thoroughly spray the foliage.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 100.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE INSECT ENEMIES OF THE
COTTON BOLL WEEVIL.

BY

W. DWIGHT PIERCE,
Agent and Expert,

ASSISTED BY

R. A. CUSHMAN AND C. E. HOOD,
Agents and Experts,

UNDER THE DIRECTION OF

W. D. HUNTER,
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In Charge of Southern Field Crop Insect Investigations.

ISSUED, APRIL 3, 1912.



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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 28, 1911.

SIR: I have the honor to transmit herewith a manuscript entitled "The Insect Enemies of the Cotton Boll Weevil," by Messrs. W. Dwight Pierce, R. A. Cushman, and C. E. Hood, agents and experts engaged in cotton boll weevil investigations. The present manuscript contains a complete summary of the studies of the boll-weevil parasites conducted since 1905. The boll weevil is now known to be attacked by 29 species of parasites and 26 species of predatory insects, most of which are indigenous to the United States. It is the purpose of this manuscript to show the sources and value of these enemies and to indicate how they may be utilized to the advantage of the farmers of the cotton belt. I recommend the publication of this manuscript as Bulletin No. 100 of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE INSECT ENEMIES OF THE COTTON BOLL WEEVIL.

INTRODUCTION.

When the cotton boll weevil first entered the United States it appeared to have almost undisputed sway. It did, in fact, escape most of its enemies. But whether parasites were introduced with it or not, we now know that within the first three years of its existence in Texas it was attacked by three important species of parasites. Year after year new factors in its control are becoming apparent, although some have probably been concerned since the beginning. On the other hand, it is certain that entirely new elements are entering the struggle as rapidly as the weevil enters new biological complexes. Among the most striking of these new elements in the control is the recent adjustment of *Microdontomerus anthonomi* Crawford (fig. 9, p. 49). This species was unknown until 1906 when a very few were taken in material reared at Cuero, Goliad, Hallettsville, Victoria, and Waco, Tex. In 1907 it was found to predominate in a portion of central Texas. In 1908 its range was found to extend northward to the Red River. In 1909 it was found as far east as the Mississippi River in Louisiana. Only a single record of the occurrence of *Sigalphus curculionis* Fitch (fig. 11, p. 53), the common parasite of the plum curculio, had been made prior to 1908. In that year it began to make its presence felt in northeastern Louisiana and western Mississippi. In 1908 a new chalcidoid parasite, recently described as *Tetrastichus hunteri* Crawford, was found to be the leading parasite of the boll weevil in northern Louisiana and western Mississippi. In 1909 this species was found as far west as Arlington, Tex.

With the advent of each new enemy and its more complete adjustment, the power for damage possessed by the weevil is by so much diminished. On the other hand, every factor which checks these enemies without also checking the weevil benefits the weevil.

If the solution of the boll-weevil problem consisted merely in adding, one by one, factors which would cut off a given percentage of the weevils, the time would not be distant when that might be accomplished. The problem is far more complicated. The various factors do not discriminate against one another, for while heat, ants, cold weather, and excessive moisture may remove many parasites from the struggle, it also follows that heat, cold weather, heavy rains,

predators, and other pests remove many ants. Proliferated plant tissue frequently acts as an important check upon the weevil, and yet in many cases it serves as a food for the weevil rather than as a controlling force. Moist weather aids the weevil. The leaf-worm, while cutting off most of the weevil food, finally is checked by parasites. Light, heat, and dryness favor certain parasites, whereas shade and moisture favor others. Parasites that are normally primary frequently waste their energies by accidentally becoming secondary, and normally secondary parasites, and probably tertiary as well, also enter the consideration. Predatory enemies fail to distinguish the parasites from the weevils, but are in turn held in check by their own enemies. The birds devour weevils, predators, and parasites, but they in turn are kept down by other birds and even man himself, and thus the complexity grows.

There are 49 species of insects which attack the immature stages of the boll weevil. Of these insects 29 species may be classed as parasitic, 5 as predatory larvæ, and 15 as predatory adults. They are divided among the orders, with 3 in the Acarina, 4 in Coleoptera, 36 in Hymenoptera, 5 in Diptera, and 1 in Lepidoptera. One of the acarians, 1 coleopteron, 15 Hymenoptera, and 1 dipteran, may be considered as quite important. A weighted average mortality of 3.93 per cent of all immature stages may be accredited to the combined factors of all parasitic enemies; the predators are responsible for 15.93 per cent, while climate is responsible for 24.45 per cent, and plant proliferation 12.42 per cent. This makes the total natural control of immature stages 56.73 per cent.

In addition to the insects attacking the boll weevils in the squares, there must be considered the insects which prey on the adults. These include one praying mantis, one predaceous bug, two beetles, and two ants—six species in all.

This bulletin is not concerned with the mortality of the weevils after they become adult because reliable figures can not be gathered upon this point. It is certain that many weevils fall prey to predaceous insects and to birds, and the well-known habits of the horned lizard would include it in the list of possible enemies. The important fact is that 56 per cent of the weevil eggs fail to produce adult weevils. The remainder is still a formidable number but the many adverse influences continue to operate upon the adults and likewise upon their progeny.

CONDUCT OF THE PARASITE PROJECT.

The investigation of the insect enemies of the cotton boll weevil was initiated in 1905. It has been conducted from the beginning by the senior author under the direction of Mr. W. D. Hunter, and with

the direct influence and encouragement of Dr. L. O. Howard, Chief of the Bureau of Entomology. Messrs. R. A. Cushman and C. E. Hood have been intimately associated in the preparation of the material for this bulletin since 1907. The collecting, examining, and recording of the immense mass of material has involved in addition the services of Messrs. E. A. Schwarz, J. D. Mitchell, W. E. Hinds, Wilmon Newell, F. C. Bishopp, A. C. Morgan, F. C. Pratt, C. R. Jones, W. W. Yothers, G. D. Smith, A. H. Rosenfeld, H. S. Smith, E. S. Tucker, T. C. Barber, S. Goes, C. S. Spooner, C. W. Flynn, T. C. Paulsen, J. A. Hyslop, V. I. Safro, T. E. Holloway, H. Pinkus, W. H. Hoffman, F. L. Elliott, and O. M. Lander. Considerable credit is due Messrs. E. A. Schwarz, J. C. Crawford, W. M. Wheeler, D. W. Coquillett, and C. H. T. Townsend for determination of the insects concerned. The weevils entering the biological complex have been determined by the senior author. In short, 33 entomologists have directly contributed the data which are herewith presented.

HISTORICAL DATA.

The first definite records of the parasites of the cotton boll weevil were made by C. H. T. Townsend in 1895 when he mentioned a small hymenopterous parasite and also recorded the suspicious occurrence of several species of *Scymnus* in the squares, and mentioned that a fungoid parasite, a species of *Cordyceps*, "was found growing out of a dead pupa in its cell in a boll, November 26, in a field in San Juan Allende, Mexico." (Townsend, 1895.) In 1901 Profs. Herrera and Rangel published notes concerning the parasitic attack of *Pediculoides ventricosus* Newport (fig. 8, p. 46) upon the boll weevil (Rangel, 1901b, 1901c).

In 1902 Dr. Wm. H. Ashmead described *Bruchophagus herreræ* from Coahuila, Mex., as a primary parasite of the boll weevil (Ashmead, 1902a, 1902b; Herrera, 1902a). This is probably *Eurytoma tylodermatis* Ashmead. Prof. Herrera also recorded the activities of a predaceous ant, *Formica fusca* Linn., subspecies *subpolita* Mayr, variety *perpilosa* Wheeler, (Herrera, 1902b; Wheeler, 1902). In the same year Prof. F. W. Mally recorded the fact that *Bracon* (now *Microbracon*) *mullitor* Say (fig. 12, p. 54) and *Eupelmus* (now *Cerambycobius*) *cyaniceps* Ashmead had been reared by him, since 1899, in considerable numbers from the boll weevil. He also recorded a species of *Eurytoma*. (Mally, 1902.)

In 1904 Hunter and Hinds recorded additional primary parasites as follows: *Sigalphus curculionis* Fitch (fig. 11, p. 53), *Cutolaccus incertus* Ashmead, *Urosigalphus* (*robustus* Ashmead), *Bracon* (*dorsator* Say), and *Eurytoma tylodermatis* Ashmead, as well as an entomogenous fungus, *Aspergillus* (Hunter and Hinds, 1904). The Urosi-

galphus has since been described as *Urosigalphus anthonomi* Crawford (Crawford, 1907a).

In 1906 Mr. Nathan Banks described a mite, *Tyroglyphus breviceps*, collected at Victoria, Tex., from boll-weevil larvæ (Banks, 1906).

In 1907 the senior author of this bulletin added *Hydnocera pubescens* LeConte as a predaceous enemy of the boll weevil (Pierce, 1907a, 1907b, 1907c). In the same year Dr. Hinds published two papers in which the work of *Solenopsis geminata* Fab. (fig. 16, p. 70), variety *xyloxi* McCook, as a predator on the boll weevil was fully discussed, and considerable statistical data on the parasitic control of the weevil were presented (Hinds, 1907a, 1907b). Mr. Morgan published a brief account of the predatory attack of a bug, *Apiomerus spissipes* Say (Morgan, 1907). Mr. J. C. Crawford described as parasites of the boll weevil *Torymus anthonomi*, *Urosigalphus anthonomi*, and *Urosigalphus schwarzi* (Crawford, 1907a).

In 1908 the senior author of this report recorded *Catolaccus anthonomi* Ashmead as a boll-weevil parasite and *Cathartus cassiæ* Reiche (*gemellatus* Duval) as a predator (Pierce, 1908a, 1908b, 1908c, 1908d). Mr. Crawford described *Cerambycobius cushmani* and *Catolaccus hunteri* as new parasites of the boll weevil (Crawford, 1908). During the same year two new predaceous enemies of the boll weevil were recorded from Louisiana, namely, *Evarthrus sodalis* LeConte and *Evarthrus* sp. (Newell and Trehearne, 1908). Mr. Townsend, in a paper on the muscoidean flies, recorded *Ennyomoma globosa* Townsend as a parasite of the boll weevil (Townsend, 1908). During 1909 Mr. Crawford described *Tetrastichus hunteri* as a parasite of the boll weevil (Crawford, 1909b).

SCOPE OF PRESENT REPORT.

The present report is supplementary to a former bulletin which was based on investigations prior to 1907 (Pierce, 1908a). The matter contained herein has mainly been gathered during the years 1907, 1908, and 1909. Only such notes as are of value for the sake of comparison have been repeated from the previous report.

The work is divided into three parts:

- I. The status of the cotton boll weevil and its enemies.
- II. The biological complex.
- III. The economic application.

PART I. THE STATUS OF THE COTTON BOLL WEEVIL AND ITS ENEMIES.

Part I of this bulletin shows the large mass of statistical material gathered during the four years of the parasite investigation, and attempts to place this material in such form as to show its economic value and significance.

The matter is arranged topically as follows:

1. A general chronological study of the insect control of the boll weevil.
2. The nature and sources of the material examined.
3. Seasonal studies of the insect control by class of infested material.
4. A geographical study of the statistics.
5. A study of the share of insect control in the mortality of immature weevils.
6. A study of how agriculture modifies insect control.
7. Climatic considerations.
8. How insect control follows the weevil dispersion.
9. The status of the boll weevil and its control by insects.
10. A brief statement of the various classes of control exercised upon the weevil.
11. Practical conclusions derived from statistical studies.

1. A GENERAL CHRONOLOGICAL STUDY OF THE INSECT CONTROL OF THE BOLL WEEVIL.

Records upon parasitic control of the boll weevil begin in July, 1902, and occur more or less scatteringly until June, 1906. The records of 1906 were very extensive, but, as will be shown, they were merely preliminary.

Table I is arranged to show the extent of the examinations made since 1902. This table should not be used to compare the records of the various years, as the manner of investigation in each year has been different, and the sources of the material have varied greatly. The table is only intended to show the total of the examinations and how these were distributed from year to year. A careful analysis of the figures has been given in the various sections of Part I.

TABLE I.—*Insect control of the boll weevil, by years.*

YEAR.	Weevil stages.	Predators.	Parasites.	Per cent mortality due to—		
				Predators.	Parasites.	All insects.
1902.....	602	(?)	7	(?)	1.16	(?)
1903.....	819	(?)	59	(?)	7.20	(?)
1905, March.....	1,005	(?)	32	(?)	3.18	(?)
1905, August.....	1,702	(?)	21	(?)	1.23	(?)
1906.....	40,073	10,547	1,728	26.31	4.31	30.62
1907.....	13,602	2,279	1,121	16.75	8.24	24.99
1908.....	29,349	3,862	2,952	13.15	10.05	23.20
1909.....	11,653	1,231	620	10.56	5.32	15.88
Totals and averages.....	98,805	.....	6,540	.....	¹ 6.61	.....

¹ This table should not be construed as indicating that parasite control has been falling off, because the table is based upon different kinds of examinations in different years. The detailed analysis of these records will be found on subsequent pages.

The figures of 1902 are based on the total number of stages reared. The data of 1903 are based on the total number of stages reared, but include both stages in hanging and fallen forms. There were 654 stages in fallen forms of which 14, or 2.14 per cent, were parasitized, and 165 stages in hanging forms of which 45, or 27.27 per cent, were parasitized. The figures of 1905 were separated to show the investigations of March and August because of the great difference in the mortality from parasites in these two months. Between 1906 and 1909 the data represent all classes of infested material and all infested regions. It will be noticed that for the last four years the total insect control of the immature weevils has fluctuated between 15 and 30 per cent.

2. NATURE AND SOURCES OF THE MATERIAL EXAMINED.

During the four years 1906-1909 examinations of mortality have been made of material collected at 6 places in Arkansas, 26 in Louisiana, 6 in Mississippi, 7 in Oklahoma, and 65 in Texas, making a total of 110 places. These examinations are based upon 94,677 stages, involving an individual examination of over 222,700 cotton forms (squares, blooms, and bolls). Many other collections and examinations were made, but because of incomplete records are excluded from the accompanying tables.

During the four years there has been the equivalent of examinations in 176 localities, or an average of 44 localities per year.

3. SEASONAL STUDIES OF INSECT CONTROL, BY CLASS OF INFESTED MATERIAL.

Very shortly after the work began in 1906 it became evident that the activity of the parasites and other insect enemies of the weevil was very different in squares and bolls, and in fallen or hanging squares or bolls, and also that the highest control by parasites was in hanging squares.

An examination of the squares of various varieties of cotton plants will show the observer that certain ones have a transverse attachment of the pedicel to the stem. In all cases where this attachment is perfectly transverse, the square when injured by any insect is caused to drop because of the separation of the infested part from the main stalk by the growth of an absciss layer at the point of attachment. (Pl. I, fig. 1; fig. 3, *a*.) Certain other varieties indicate a long diagonal attachment to the stem. When these squares are injured, a diagonal absciss layer is formed which runs down the stem from one-half to three-fourths of an inch or even more. This layer is generally incomplete at the lower point and consequently the square

hangs by a few threads and dries on the plant. (Pl. I, fig. 2; fig. 3, *b*.) To these squares and bolls which thus hang, we have applied the terms "hanging squares" and "hanging bolls."

Tables II and III, which are arranged to show the monthly percentages of control by parasites, by predators, and by all insects, illustrate the differences in the control of the weevil in the four principal classes of infested material, namely, fallen and hanging dry squares, and fallen and hanging dry bolls.

A few words of explanation of these tables are necessary in order to show what is meant by the different classes of mortality. It has been found that a large number of stages are destroyed as eggs or young larvæ by the proliferation of the plant tissues. At the time of the examination for mortality of the weevil, all evidence of the weevils destroyed in these stages has disappeared; consequently the percentages of mortality given in the following tables are the percentages of stages found which are killed by the causes enumerated, and the mortality from proliferation is entirely ignored.

TABLE II.—*Monthly mortality of the boll weevil due to insects in fallen squares.*

Month.	Squares exam- ined.	Stages found.	Stages killed by—			Percentage of stages killed.			
			Cli- mate.	Preda- tors.	Para- sites.	Total.	Preda- tors.	Para- sites.	All insects.
1906.									
June.....	4,476	3,831	1,797	914	118	73.8	23.8	3.1	26.9
July.....	7,265	4,552	1,676	1,070	207	65.1	23.6	4.7	28.3
August.....	19,305	11,186	2,828	4,065	180	63.5	36.6	1.7	38.3
September.....	10,709	5,365	1,475	1,625	285	63.0	30.2	5.4	35.6
October.....	1,981	600	205	133	33	61.8	22.1	5.6	27.7
Totals and averages for 1906	43,736	25,534	7,981	7,848	823	65.2	30.7	3.3	34.0
1907.									
June.....	2,074	1,261	339	198	76	48.6	15.6	7.0	22.6
July.....	5,192	3,608	778	433	133	37.2	11.9	3.8	15.7
August.....	7,400	5,058	2,156	1,372	155	72.8	27.1	3.0	30.1
November.....	150	93	90	0	1	97.7	0	1.0	1.0
Totals and averages for 1907	14,816	10,020	3,363	2,003	365	57.1	19.9	3.7	23.6
1908.									
May.....	100	56	4	0	2	10.7	0	3.5	3.5
June.....	7,808	5,285	1,169	866	324	44.6	16.4	6.1	22.5
July.....	7,437	4,690	1,047	902	219	46.2	19.2	4.7	23.9
August.....	1,941	1,208	540	294	63	74.2	24.3	5.2	29.5
September.....	7,180	3,894	578	815	136	39.2	20.9	3.5	24.4
October.....	9,678	5,342	807	289	659	32.8	5.4	12.3	17.7
November.....	604	369	90	1	88	51.1	2.7	22.6	25.3
Totals and averages for 1908	34,757	20,844	4,235	3,167	1,491	42.7	15.2	7.1	22.3
1909.									
January.....	50	23	0	0	0	0	0	0	0
July.....	7,677	4,334	1,318	507	131	45.1	11.7	3.0	14.7
August.....	5,507	2,866	680	428	38	39.9	14.9	1.3	15.2
September.....	750	364	19	5	1	6.8	1.4	.3	1.7
Totals and averages for 1909	13,984	7,587	2,017	940	170	41.2	12.4	2.2	14.6

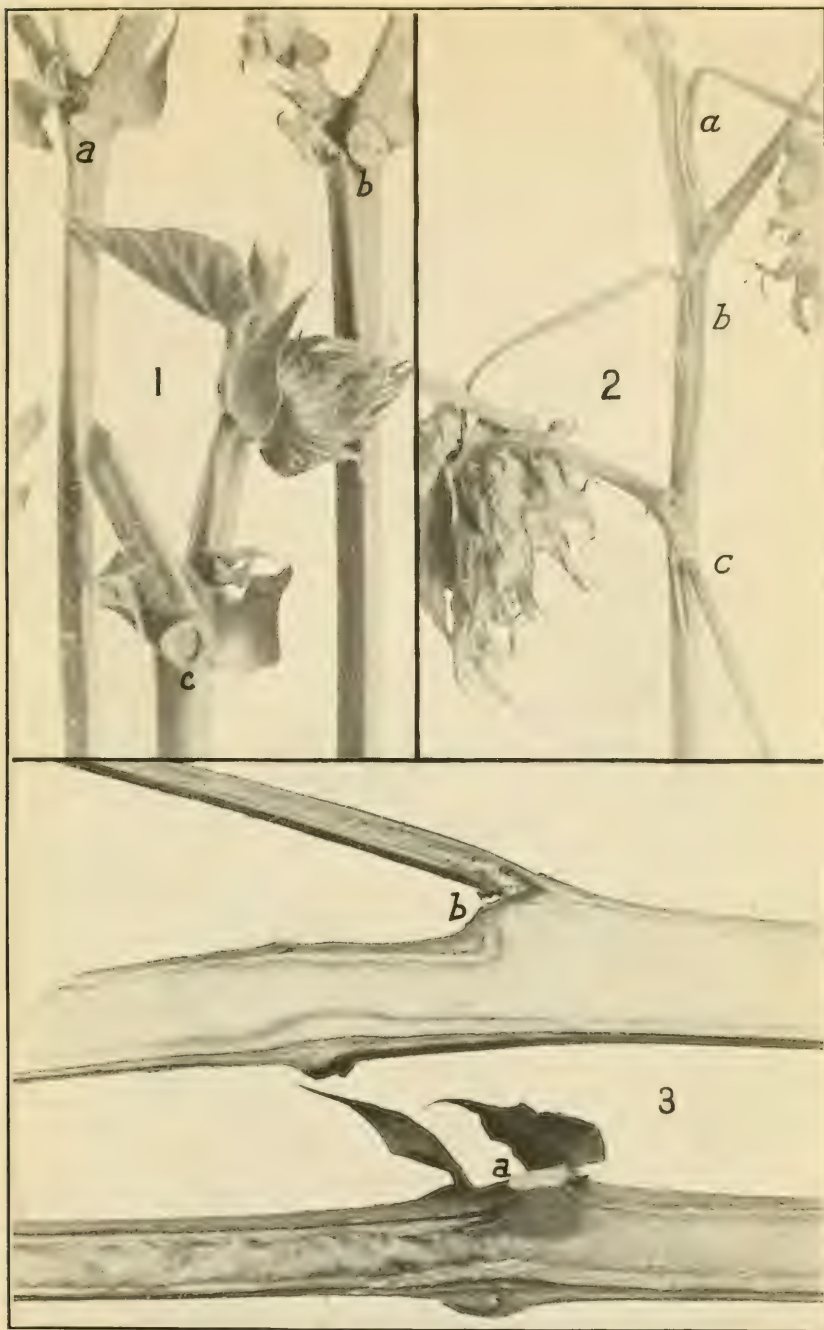
A study of Table II, on the mortality due to insects in fallen squares, shows that the principal insect work is that of predatory insects and, furthermore, that the total insect control is, as a rule, less than the climatic control. The table embraces the examination of 63,985 weevil stages of which 17,596 were killed by climate, 13,958 by predators, and 2,849 by parasites. In other words, the average percentage of control in fallen squares by all kinds of insects is 26.2 per cent, or 21.8 per cent by predators and 4.4 per cent by parasites.

A further study of Table II shows that the predators have in each year done their most valuable work in the month of August. The parasites, however, have shown considerable variation in the month of their best work. In 1906 the highest average percentage was in October; in 1907 it was in June; in 1908 in November; and in 1909 in July.

TABLE III.—*Monthly mortality of the boll weevil due to insects in hanging squares.*

Months.	Squares examined.	Stages found.	Stages killed by—			Percentage of stages killed.			
			Cli- mate.	Preda- tors.	Para- sites.	Total.	Preda- tors.	Para- sites.	All in- sects.
1906									
July.....	474	247	47	20	76	57.9	8.0	21.0	29.0
August.....	4,165	2,566	539	544	337	55.3	21.2	13.1	34.3
September.....	2,032	1,285	245	269	125	49.7	20.9	9.7	30.6
October.....	33	20	4	10	0	70.0	50.0	0	50.0
Totals and averages for 1906.....	6,704	4,118	835	843	538	53.8	20.5	13.0	33.5
1907									
June.....	150	88	26	5	13	50.0	5.7	14.7	20.4
July.....	956	513	57	16	103	34.3	3.1	20.1	23.2
August.....	3,543	2,011	296	175	580	52.2	8.7	28.8	37.5
Totals and averages for 1907.....	4,649	2,612	379	196	696	48.6	7.5	26.6	34.1
1908									
July.....	2,955	2,177	395	179	479	48.4	8.2	22.0	30.2
August.....	1,393	842	141	91	279	60.7	10.8	33.1	43.9
September.....	3,922	2,340	476	259	410	48.9	11.0	17.5	28.5
October.....	1,192	553	116	53	113	52.9	10.0	21.2	31.2
November.....	1,125	10	8	0	0	80.0	0	0	0
Totals and averages for 1908.....	10,587	5,922	1,136	582	1,281	50.9	9.8	21.7	31.5
1909									
January.....	80	3	0	0	0	0	0	0	0
July.....	630	383	36	31	117	48.0	8.1	30.5	38.6
August.....	1,290	856	96	72	88	29.9	8.4	10.3	18.7
September.....	745	496	61	21	76	31.9	4.2	15.3	19.5
November.....	136	52	14	0	30	100.0	0	68.0	68.0
December.....	515	169	47	1	71	70.4	6	42.0	42.6
Totals and averages for 1909.....	3,396	1,959	254	125	382	38.8	6.4	19.5	25.9

Table III shows that the principal insect work in hanging squares is that of parasitic insects and, furthermore, that the total insect control in hanging squares is each year higher than the climatic control. This table embraces the examination of 14,611 weevil



SHEDDING AND RETENTION OF FORMS ON THE COTTON PLANT.

Fig. 1.—*a, b, c*, Normal scars left by shed forms. Fig. 2.—*a, b, c*, Abnormal scars with forms retained. Fig. 3.—*a*, Longitudinal section through base of shed form; *b*, Longitudinal section through base of retained form. Fig. 1, natural size; fig. 2, somewhat reduced; fig. 3, enlarged two diameters. (After Hinds.)

stages of which 2,604 were killed by climate, 1,746 by predators, and 2,897 by parasites. In other words the average percentage of control by all kinds of insects is 31.61 per cent, or 11.93 per cent by predators and 19.68 per cent by parasites. It appears that July and August are usually the best months for parasite control in hanging squares.

TABLE IV.—*Monthly mortality of the boll weevil due to insects in hanging bolls.*

Months.	Bolls examined.	Stages found.	Stages killed by—			Percentage of stages killed.			
			Cli- mate.	Preda- tors.	Para- sites.	Total.	Preda- tors.	Para- sites.	All in- sects.
1906									
June.....	145	0	0	0	0	0.0	0.0	0.0	0.0
July.....	2,947	290	28	14	0	14.5	4.8	0	4.8
August.....	23,454	2,977	416	742	19	39.5	24.9	.6	25.5
September.....	6,210	1,555	198	188	23	26.3	12.1	1.5	13.6
October.....	399	147	21	11	3	23.8	7.5	2.0	9.5
Totals and averages for 1906	33,155	4,969	663	955	45	35.9	21.9	0.9	22.8
1907									
June.....	50	5	1	0	1	40.0	0	20.0	20.0
July.....	50	7	1	0	0	14.3		0	0
August.....	1,272	330	115	51	4	51.5	15.4	1.2	16.6
Totals and averages for 1907	1,372	342	117	51	5	50.6	14.9	1.4	16.3
1908									
June.....	2,227	238	34	6	21	29.7	2.5	8.8	11.3
July.....	4,450	405	125	26	13	40.5	6.4	3.2	9.6
August.....	1,123	200	22	20	0	21.0	10.0	0	10.0
September.....	933	98	8	4	1	13.2	4.1	1.0	5.1
Totals and averages for 1908	8,733	941	189	56	35	29.7	5.9	3.7	9.6
1909									
January.....	1,616	402	133	25	11	42.0	6.2	2.7	8.9
February.....	716	115	12	49	2	54.7	42.6	1.7	44.3
March.....	608	56	14	12	1	48.2	21.4	1.7	23.1
Totals and averages for 1909.	2,940	573	159	86	14	45.2	15.0	2.4	17.4

In fallen bolls the principal insect work is that accomplished by predatory insects, and the total insect control has been less than the climatic control except in the year 1906. Table IV covers an examination of 6,825 weevil stages, of which 1,128 were killed by climate, 1,148 by predators, and only 99 by parasites. This means that 18.2 per cent of all the stages were killed by insects, or 16.8 per cent by predators and 1.4 per cent by parasites. In this class of infested forms it is also noticeable that the principal work by the predators is accomplished during the month of August.

TABLE V.—*Monthly mortality of the boll weevil due to insects in hanging bolls.*

Month.	Bolls exam- ined.	Stages found.	Stages killed by—			Percentage of stages killed.			
			Cli- mate.	Pred- ators.	Para- sites.	Total.	Pred- ators.	Para- sites.	All insects.
1906.									
July.....	434	22	2	3	0	22.6	13.6	0.0	13.6
August.....	8,762	2,444	281	340	155	31.7	13.9	6.3	20.2
September.....	4,224	1,627	130	292	101	32.1	17.9	6.2	24.1
October.....	3,629	1,359	186	266	66	38.2	19.6	4.8	24.4
Totals and averages for 1906.....	17,049	5,452	599	901	322	33.4	16.5	5.9	22.4
1907.									
July.....	460	38	2	0	0	5.3	0	0	0
August.....	683	393	35	13	50	25.0	3.6	12.5	16.1
Totals and averages for 1907.....	1,143	431	37	13	50	23.2	3.0	11.6	14.6
1908.									
February.....	12,451	515	424	0	54	92.8	0	10.5	10.5
March.....	1,239	22	21	0	1	100.0	0	4.5	4.5
July.....	2,132	492	63	37	58	32.0	7.5	11.7	19.1
August.....	720	191	23	7	22	27.2	3.6	11.5	15.1
September.....	664	83	7	17	2	31.3	20.4	2.4	22.8
October.....	432	262	36	11	5	19.8	4.2	1.9	6.1
November.....	519	274	134	1	8	52.2	.3	2.9	3.2
Totals and averages for 1908.....	18,157	1,839	708	73	150	50.6	3.9	8.1	12.0
1909.									
January.....	3,941	857	335	38	43	48.5	4.4	5.0	9.4
February.....	430	35	13	11	0	68.6	31.4	0	31.4
March.....	653	81	16	16	0	39.5	19.7	0	19.7
August.....	365	42	1	2	0	8.1	5.4	0	5.4
December.....	2,148	519	217	13	11	46.4	25.0	2.1	27.1
Totals and averages for 1909.....	7,537	1,534	582	80	54	46.7	5.2	3.5	8.7

Table V was based, as may be seen, upon the examination of 9,256 weevil stages, of which 1,926 were killed by climate, 1,067 by predators, and 576 by parasites. In other words, the insect enemies killed 17.74 per cent, of which 11.52 per cent were killed by predators and 6.22 per cent by parasites. July and August are the principal months for attack upon hanging bolls.

Summarizing the four preceding tables, Table VI is presented to show the monthly rate of mortality in all classes of infested forms.

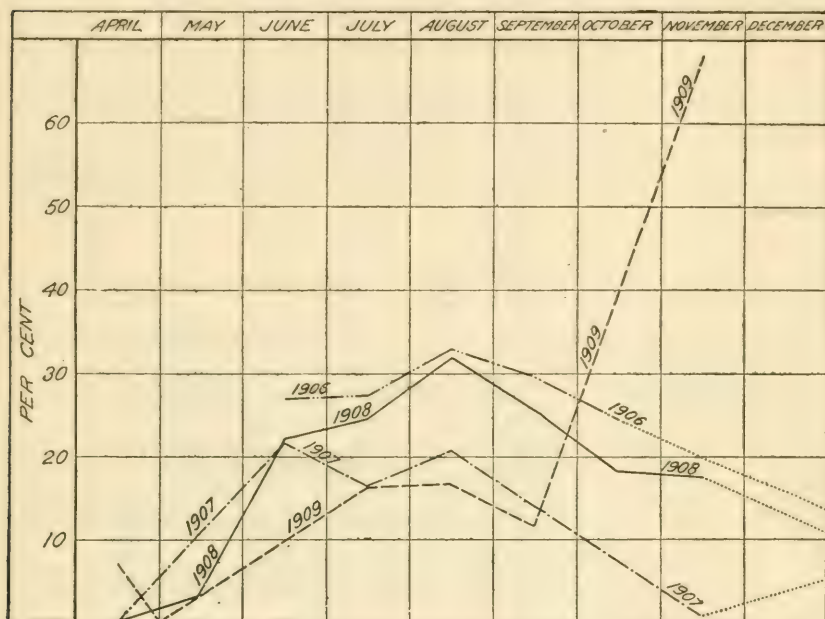


FIG. 1.—Diagram illustrating the monthly percentage of mortality of immature boll weevils due to insect enemies. (Original.)

It will be noticed that in each year certain months have been omitted and it must be explained that the reason therefor has been the necessity of making these examinations only when other work was not pressing. An analysis of this table is more readily made by reference to the accompanying diagram (fig. 1), which demonstrates conclusively that August is the month during which the insect enemies of the boll weevil are most active.

TABLE VI.—*Monthly rate of mortality of the boll weevil in infested forms of all classes*

Month.	Forms exam- ined.	Stages found.	Percentage of stages killed by—				
			All causes.	Climate.	Preda- tors.	Para- sites.	All insects.
1906.							
June.....	4,621	3,831	73.80	46.90	23.80	3.10	26.90
July.....	11,120	5,111	61.67	34.29	21.83	5.53	27.36
August.....	55,686	19,173	54.64	21.19	29.32	3.61	32.93
September.....	23,175	9,832	50.40	20.80	24.14	5.43	29.57
October.....	6,042	2,126	44.12	19.56	19.75	4.79	24.54
Totals and averages for 1906	100,644	40,073	55.81	25.15	26.31	4.31	30.62
1907.							
June.....	2,274	1,354	48.67	27.03	14.99	6.64	21.63
July.....	6,658	4,166	36.55	20.11	10.77	5.66	16.43
August.....	12,898	7,792	64.19	33.39	20.67	10.12	30.79
November.....	150	93	97.70	96.70	0	1.00	1.00
Totals and averages for 1907	21,980	13,405	54.27	29.06	16.88	8.32	25.20
1908.							
February.....	12,451	515	92.81	82.33	0	10.48	10.48
March.....	1,329	22	100.00	95.50	0	4.50	4.50
May.....	100	56	10.70	7.20	0	3.50	3.50
June.....	10,035	5,523	43.81	15.78	15.78	6.24	22.02
July.....	16,974	7,764	45.63	20.99	14.73	9.90	24.63
August.....	5,177	2,441	61.53	29.79	16.87	14.91	31.78
September.....	12,708	6,415	42.29	16.66	17.06	8.55	25.61
October.....	11,302	6,157	33.92	15.57	5.73	12.61	18.34
November.....	2,248	653	50.53	35.52	3.06	14.70	17.76
Totals and averages for 1908	72,234	29,546	44.34	21.21	13.12	10.00	23.12
1909.							
January.....	5,687	1,285	45.52	36.42	4.90	4.20	9.10
February.....	1,146	150	58.00	16.66	40.00	1.33	41.33
March.....	1,261	137	43.06	21.89	20.43	.72	21.15
July.....	8,307	4,717	45.36	28.70	11.19	5.25	16.34
August.....	7,162	3,764	37.32	20.64	13.33	3.34	16.67
September.....	1,495	860	21.25	9.30	3.02	8.95	11.97
November.....	136	52	100.00	32.00	0	68.00	68.00
December.....	2,663	688	52.32	38.37	2.03	11.91	13.94
Totals and averages for 1909	27,857	11,653	41.73	25.84	10.56	5.32	15.88

4. A GEOGRAPHIC STUDY OF THE STATISTICS OF INSECT CONTROL.

A study of these same statistics, when arranged to show the insect control by States, has given much interesting light upon the subject of the control of the weevil.

In fallen squares we find an average for total insect control of 26.8 per cent in Oklahoma, 25.9 per cent in Mississippi, 24.5 per cent in Texas, 20.6 per cent in Louisiana, and 12.5 per cent in Arkansas. Analyzing these figures from another standpoint, we find that the State of Mississippi leads in parasite control with 14.27 per cent, Oklahoma standing next with 4.71 per cent, Texas with 3.9 per cent, Louisiana with 2.52 per cent, and Arkansas with 0.71 per cent. The relative rank of the States for predatory control is quite different. Oklahoma leads with 22.16 per cent, Texas comes next with 20.6 per cent, Louisiana with 18.1 per cent, Arkansas with 11.82 per cent, and Mississippi with 11.63 per cent. In climatic control Texas leads

with 37.9 per cent, Oklahoma comes next with 30.8 per cent, Arkansas with 25.65 per cent, Louisiana with 12.5 per cent, and Mississippi with 11.7 per cent. Thus it may be seen that the dry, prairie States of Texas and Oklahoma lead in the climatic and predatory control of the weevil and also in the total amount of control, and that the climatic control in each of these States is greater than the total insect control. This latter fact is also true of Arkansas. In Louisiana and Mississippi, States which are naturally more humid, the climate has less influence and the greater proportion of the control is by the insect enemies.

In hanging squares the conditions are entirely reversed. It is noticeable that Oklahoma leads in parasitism with an average of 31.74 per cent, Texas averages 26.6 per cent, Arkansas 24.16 per cent, Mississippi 21.2 per cent, and Louisiana 12.07 per cent. In predatory control Louisiana leads with 12.9 per cent, Texas comes next with 10.9

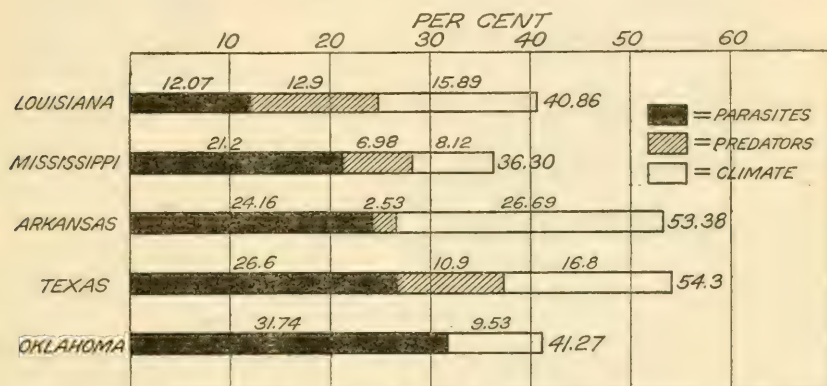


FIG. 2.—Diagram illustrating the average climatic and insect control of the immature boll weevils during 1906, 1907, 1908, and 1909, in hanging squares. (Original.)

per cent, Mississippi with 6.98 per cent, and Arkansas with 2.53 per cent. We have no record of predatory control in Oklahoma. In all five States insect control in hanging squares is greater than climatic control. With regard to climatic control Arkansas leads with 26.69 per cent, Texas has 16.8 per cent, Louisiana 15.89 per cent, Oklahoma 9.53 per cent, and Mississippi 8.12 per cent. These statistics are graphically shown in figures 2 and 3.

A brief comparison of the condition in hanging and fallen squares will show that the States of Texas and Oklahoma have a higher average percentage of control from all factors in fallen squares than in the hanging squares; the States of Louisiana and Arkansas have a higher average percentage of control from all factors in hanging squares than in fallen squares, and in the State of Mississippi the difference is very slight, although in favor of the fallen squares. This illustrates the

difficulty of giving any single recommendation for the control of the boll weevil which would apply to all regions. This point will be brought out more fully in other sections of this bulletin.

5. A STUDY OF THE SHARE OF INSECT CONTROL IN THE MORTALITY OF IMMATURE BOLL WEEVILS.

The condensed tables which have been presented are likely to give the impression that the parasite control of the weevil is on an average very low, but it must be remembered that the examinations have been made in all parts of the infested region whether the weevil has been present 17 years or only a few months, and whether the weevil damage amounts to less than 1 per cent of the crop or to almost 100

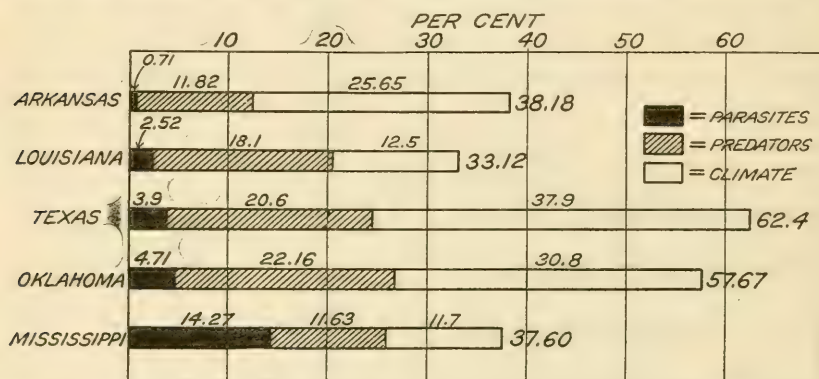


FIG. 3.—Diagram illustrating the average climatic and insect control of the immature boll weevils during 1906, 1907, 1908, and 1909, in fallen squares. (Original.)

per cent. This great difference in the sources of the material examined has necessarily lowered the average mortality to its minimum. The following records show some of the cases of very high mortality due to parasites:

Highest records of parasitism of the boll weevil.

IN FALLEN SQUARES.

Locality.	Date.	Number of stages.	Percentage of parasitism.
Robson, La.....	Nov. 5, 1907.....	53	77.26
Corpus Christi, Tex.....	June 20, 1907.....	92	36.95
Natchez, Miss.....	Oct. 23, 1908.....	157	28.6
Dallas, Tex.....	Aug. 12, 1908.....	18	27.78
Goliad, Tex.....	July 28, 1908.....	114	26.63
Natchez, Miss.....	Oct. 16, 1908.....	230	21.7
Cuero, Tex.....	Aug. 12, 1907.....	105	19.04
Natchez, Miss.....	July, 1909.....	200	18.5
Shreveport, La.....	Oct. 29, 1908.....	624	15.8
Victoria, Tex.....	June 19, 1908.....	513	14.5
Roosevelt, Tex.....	Sept. 24, 1906.....	69	14.4
Arlington, Tex.....	July 17, 1908.....	382	13.35
Brownsville, Tex.....	Sept. 5, 1906.....	1,147	12.4
Denison, Tex.....	July, 1909.....	494	8.5
Atoka, Okla.....	Sept. 2, 1908.....	100	8.0

Highest records of parasitism of the boll weevil—Continued.

IN HANGING SQUARES.

Locality.	Date.	Number of stages.	Percentage of parasitism.
Waco, Tex.	July 23, 1909.	39	66.6
Arlington, Tex.	July, 1909.	55	63.63
Victoria, Tex.	Aug. 5, 1907.	26	61.5
Dallas, Tex.	Aug. 17, 1907.	82	59.7
Arlington, Tex.	July 17, 1908.	51	56.86
Dallas, Tex.	July, 1909.	57	52.63
Waco, Tex.	July 25, 1906.	99	52.6
Navasota, Tex.	Aug. 17, 1908.	29	51.75
Natchez, Miss.	Oct. 23, 1908.	82	51.3
San Antonio, Tex.	July 24, 1908.	29	48.27
Hallettsville, Tex.	July 1, 1907.	19	47.3
Dallas, Tex.	Aug. 10, 1907.	193	47.15
Arlington, Tex.	Aug. 6, 1908.	260	46.92
Victoria, Tex.	July 29, 1908.	140	45.71
Foster, La.	Sept. 7, 1907.	22	45.47
Tallulah, La.	Dec. 20, 1909.	85	44.7
Forbing, La.	Aug. 29, 1907.	41	43.9
Shreveport, La.	Oct. 28, 1908.	37	37.84
Hope, Ark.	Sept. 16, 1908.	69	33.33
Ada, Okla.	Sept. 4, 1908.	63	31.74
Fouke, Ark.	July 27, 1908.	284	26.05
Waco, Tex.	Sept. 20, 1906.	109	23.8
Cuero, Tex.	Aug. 31, 1906.	347	21.3
Tallulah, La.	Sept., 1909.	495	15.35

IN FALLEN BOLLS.

Victoria, Tex.	June 17-29, 1908.	97	14.4
Alexandria, La.	July 29, 1908.	22	9.09
Trinity, Tex.	Aug. 24, 1907.	12	8.3
Corsicana, Tex.	Sept. 18, 1906.	34	5.9
Victoria, Tex.	Jan., 1909.	87	5.74

IN HANGING BOLLS.

Denison, Tex.	Aug. 27, 1907.	11	36.3
Calvert, Tex.	Aug. 28, 1907.	20	30.0
Goliad, Tex.	July 28, 1908.	38	26.31
Do.	do.	38	26.31
San Antonio, Tex.	July 24, 1908.	35	25.71
Victoria, Tex.	Aug. 10, 1907.	110	22.7
Natchez, Miss.	Jan., 1909.	125	14.4
Marshall, Tex.	Aug. 22, 1906.	52	13.5
Trinity, Tex.	Aug. 9, 1906.	142	12.0
Waco, Tex.	Sept. 20, 1906.	303	11.8

These records give merely the highest percentages for each State in each year. There are many other records which might be included between the above figures.

Highest records of total insect control of the boll weevil.

IN FALLEN SQUARES.

Locality.	Date.	Number of stages.	Percentage of insect control.
Athens, Tex.	Aug. 1, 1907.	255	96.11
Hallettsville, Tex.	Aug. 1, 1908.	100	92.00
Overton, Tex.	Aug. 1, 1906.	197	85.20
Beeville, Tex.	do.	1,310	78.50
Victoria, Tex.	July 29, 1908.	375	78.38
Beeville, Tex.	Sept. 1, 1906.	678	77.40
Cuero, Tex.	June 20, 1908.	549	73.60
Goliad, Tex.	Aug. 28, 1908.	114	66.69
Vidalia, La.	Sept. 15, 1908.	142	61.20
Sherman, Tex.	July, 1909.	171	49.71

Highest records of total insect control of the boll weevil—Continued.

IN HANGING SQUARES.

Locality.	Date.	Number of stages.	Percentage of insect control.
Athens, Tex.....	Aug. 1, 1907.....	75	84.00
Arlington, Tex.....	July, 1909.....	55	75.44
Dallas, Tex.....	do.....	57	69.99
Victoria, Tex.....	July 29, 1908.....	87	58.54
Waco, Tex.....	July 1, 1906.....	99	56.56
Mansfield, La.....	Sept. 1, 1906.....	244	50.90
Victoria, Tex.....	Aug. 1, 1907.....	253	50.00

IN HANGING BOLLS.

Mansfield, La.....	Sept. 29, 1906.....	145	58.30
Waco, Tex.....	Aug. 1, 1906.....	421	42.04
Overton, Tex.....	do.....	89	40.50
Mansfield, La.....	Sept. 24, 1906.....	479	33.00

THE CORRECT BASIS FOR COMPARISON OF MORTALITY STATISTICS.

As has been explained, the examinations have been made from various sources. It is therefore necessary to arrive at some true basis for the comparison of these data before an exact knowledge of the conditions existing can be obtained. The first mortality of the weevil is that due to proliferation. Dr. Hinds, in Bulletin 59 of this bureau, has shown that the average mortality of weevil stages in squares from proliferation is 13.5 per cent and that the average mortality in bolls is 6.3 per cent. In the absence of further data these two percentages are used as a basis for obtaining the weighted average mortality.

As nearly as the proportion can be estimated throughout the entire season, 15 per cent of the weevil stages are to be found in bolls and 5 per cent in hanging forms. Whether these arbitrary estimates be true or not, this is the only manner in which it will be possible to compare the mortality by the different factors in the various years. On this basis, therefore, a series of hypothetical tables has been erected.

In order to show how the hypothetical average differs from the average obtained from the total examinations, two tables are given for each year, the first being a table giving the actual conditions in the four classes of infested material and the second table being a hypothetical table based upon 10,000 weevil stages on the arbitrary basis of 5 per cent of the stages in hanging forms and 15 per cent of the stages in bolls. The process continues by first subtracting the mortality by proliferation and then computing the mortality from climate, predators, and parasites from the remainder. The percentages of mortality given in the total line are based upon the total of 10,000 stages.

1906.—The data on the mortality of the weevil in 1906 may therefore be condensed and tabulated as follows:

TABLE VII.—*Boll-weevil mortality in 1906.*

Class of forms.	Number of weevil stages.	Percentage of stages alive.	Percentage of stages killed by—			Total percentage of mortality.
			Climate.	Predators.	Parasites.	
Hanging bolls.....	5,452	66.59	10.98	16.52	5.90	33.41
Hanging squares.....	4,118	46.20	20.30	20.50	13.00	53.80
Fallen bolls.....	4,969	64.53	13.34	19.01	.90	35.47
Fallen squares.....	25,534	34.80	31.20	30.70	3.30	65.20
Totals and averages.....	40,073	44.19	25.15	26.31	4.31	55.84

TABLE VIII.—*The hypothetical or weighted average mortality of the boll weevil, 1906.¹*

Class of forms.	Percentage of total number of stages.	Number of stages.	1906—Mortality from—											
			Prolifera- tion.		Remainder.	Climate.		Predators.		Parasites.		Total.		
			Percentage of total.	Number killed.		Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of total.	Number killed.	
Hanging bolls.....	0.75	75	6.30	4.7	70.3	10.98	7.7	16.52	11.6	5.90	4.1	37.4	28.1	
Hanging squares.....	4.25	425	13.50	57.4	367.6	20.30	74.6	20.50	75.4	13.00	47.8	60.0	255.2	
Total hanging..	5.00	500	.....	62.1	437.9	.....	82.3	.....	87.0	.....	51.9	.....	283.3	
Fallen bolls.....	14.25	1,425	6.30	90.0	1,335.0	13.34	178.1	19.01	253.8	.90	12.0	37.4	533.9	
Fallen squares.....	80.75	8,075	13.50	1,090.1	6,984.9	31.20	2,179.3	30.70	2,144.4	3.30	230.5	69.8	5,644.3	
Total fallen.....	95.00	9,500	.....	1,180.1	8,319.9	.....	2,357.4	.....	2,398.2	.....	242.5	.....	6,178.2	
Totals and aver- ages.....	100.00	10,000	12.42	1,242.1	.....	24.39	2,439.7	24.85	2,485.2	2.94	294.4	64.61	6,461.5	

¹ Given 10,000 weevil stages.

1907.—The mortality during 1907 was 54.27 per cent when figured from the total number of stages and total mortality, thus showing a decrease of 1.54 per cent from the mortality of 1906 figured in the same manner. The parasitism showed an increase of 4.01 per cent.

TABLE IX.—*Boll-weevil mortality in 1907.*

Class of forms.	Number of weevil stages.	Percentage of stages alive.	Percentage of stages killed by—			Total percentage of mortality.
			Climate.	Predators.	Parasites.	
Hanging bolls.....	431	76.80	8.58	3.02	11.60	23.20
Hanging squares.....	2,612	51.40	14.50	7.50	26.60	48.60
Fallen bolls.....	342	49.42	31.28	14.91	1.46	50.58
Fallen squares.....	10,020	42.90	33.50	19.90	3.70	57.10
Totals and averages.....	13,405	45.73	29.06	16.88	8.32	54.27

Following the plan adopted for the 1906 records these figures may be weighted for comparison with the earlier records.

TABLE X.—*The hypothetical or weighted average mortality of the boll weevil in 1907.*¹

Class of forms.	Percentage of total number of stages.	Number of stages.	1907—Mortality from —										
			Proliferation.		Remainder.	Climate.		Predators.		Parasites.		Total.	
			Percentage of total.	Number killed.		Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of total.	Number killed.
Hanging bolls.....	0.75	75	6.30	4.7	70.3	8.58	6.0	3.02	2.1	11.60	8.1	29.70	20.9
Hanging squares.....	4.25	425	13.50	57.4	367.6	14.50	53.3	7.50	27.7	26.60	97.8	55.50	236.2
Total hanging..	5.00	500	.....	62.1	437.9	.....	59.3	.....	29.8	.....	105.9	.....	257.1
Fallen bolls.....	14.25	1,425	6.30	90.0	1,335.0	31.28	417.6	14.91	199.0	1.46	19.5	50.90	726.1
Fallen squares.....	80.75	8,075	13.50	1,090.1	6,984.9	33.50	2,339.6	19.90	1,389.8	3.70	258.4	62.80	5,077.9
Total fallen.....	95.00	9,500	.....	1,180.1	8,319.9	.....	2,757.2	.....	1,588.8	.....	277.9	.....	5,804.0
Totals and averages.....	100.00	10,000	12.42	1,242.1	.....	28.16	2,816.5	16.18	1,618.6	3.83	383.8	60.61	6,061.1

¹ Given 10,000 weevil stages.

This table shows a weighted increase of 0.89 per cent for parasites and a weighted decrease of 4 per cent for all agencies due to the falling off in control by predators.

1908.—The mortality during 1908 was 44.34 per cent when figured from the total number of stages, the total mortality thus showing a decrease of 9.93 per cent from 1907. The parasitism showed an increase of 1.68 per cent.

TABLE XI.—*Boll-weevil mortality in 1908.*

Class of forms.	Number of weevil stages.	Percentage of stages alive.	Percentage of stages killed by—			
			Climate.	Predators.	Parasites.	All agencies.
Hanging bolls.....	1,839	49.40	38.48	3.97	8.15	50.60
Hanging squares.....	5,922	49.01	19.24	9.80	21.70	50.99
Fallen bolls.....	941	70.25	20.08	5.95	3.71	29.75
Fallen squares.....	20,844	57.28	20.30	15.18	7.15	42.72
Totals and averages.....	29,546	55.66	21.21	13.12	10.00	44.34

Following the plan adopted for the 1906 and 1907 records these figures may be weighted for comparison with the earlier records.

TABLE XII.—*The hypothetical or weighted average mortality of the boll weevil in 1908.*¹

Class of forms.	Percentage of total number of stages.	Number of stages.	1908—Mortality from —										
			Prolifer-ation.		Remainder.	Climate.		Predators.		Parasites.		Total.	
			Percentage of total.	Number killed.		Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of total.	Number killed.
Hanging bolls.....	0.75	75	6.30	4.7	70.3	38.48	27.1	3.97	1.4	8.15	5.7	51.80	38.9
Hanging squares.....	4.25	425	13.50	57.4	367.6	19.24	70.7	9.80	36.0	21.70	79.8	57.30	243.9
Total hanging..	5.00	500	.....	62.1	437.9	.....	97.8	.....	37.4	.....	85.5	.....	282.8
Fallen bolls.....	14.25	1,425	6.30	90.0	1,335.0	20.08	268.1	5.95	79.4	3.71	49.5	34.10	487.0
Fallen squares.....	80.75	8,075	13.50	1,090.1	6,984.9	20.30	1,417.9	15.18	1,060.3	7.15	499.4	50.30	4,067.7
Total fallen.....	95.00	9,500	.....	1,180.1	8,319.9	.....	1,686.0	.....	1,139.7	.....	548.9	.....	4,554.7
Totals and averages.....	100.00	10,000	12.42	1,242.2	.....	17.83	1,783.8	11.77	1,177.1	6.34	634.4	48.37	4,837.5

¹ Given 10,000 weevil stages.

This table shows a weighted increase of 2.51 per cent for parasites and a weighted decrease of 12.24 per cent for all agencies, due to the falling off in control by both climate and predators.

1909.—The mortality during 1909 was 41.73 per cent when figured from the total number of stages, the total mortality thus showing a decrease of 2.61 per cent from 1908. The parasitism showed also a decrease amounting to 4.68 per cent.

TABLE XIII.—*Boll-weevil mortality in 1909.*

Class of forms.	Number of weevil stages.	Percentage of stages alive.	Percentage of stages killed by—			
			Climate.	Predators.	Parasites.	All agencies.
Hanging bolls.....	1,534	53.33	37.94	5.21	3.52	46.67
Hanging squares.....	1,959	61.16	12.96	6.38	19.49	38.84
Fallen bolls.....	573	54.82	27.74	15.00	2.44	45.18
Fallen squares.....	7,587	58.79	26.58	12.39	2.24	41.21
Totals and averages.....	11,653	58.27	25.84	10.56	3.32	41.73

Following the plan adopted for the three preceding years these figures may be weighted for comparison with the earlier records:

TABLE XIV. — *The hypothetical or weighted average mortality of the boll weevil in 1909.*¹

Class of forms.	Percentage of total number of stages.	Number of stages.	1909—Mortality from—										
			Proliferation.		Remainder.	Climate.		Predators.		Parasites.		Total.	
			Percentage of total.	Number killed.		Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of remainder.	Number killed.	Percentage of total.	Number killed.
Hanging bolls.....	0.75	75	6.30	4.7	70.3	37.94	26.7	5.21	3.7	3.52	2.5	50.13	37.6
Hanging squares.....	4.25	425	13.50	57.4	367.6	12.96	47.6	6.38	23.4	19.49	71.6	47.29	200.0
Total hanging..	5.00	500	.....	62.1	437.9	.....	74.3	.....	27.1	.....	74.1	.....	237.6
Fallen bolls.....	14.25	1,425	6.30	90.0	1,335.0	27.74	370.3	15.00	200.2	2.44	32.6	48.63	693.1
Fallen squares.....	80.75	8,075	13.50	1,090.1	6,984.9	26.58	1,856.6	12.39	865.4	2.24	156.5	49.14	3,968.6
Total fallen.....	95.00	9,500	.....	1,180.1	8,319.9	.....	2,226.9	.....	1,065.6	.....	189.1	.....	4,661.7
Totals and averages.....	100.00	10,000	12.42	1,242.2	.....	23.01	2,301.2	10.92	1,092.7	2.63	263.2	48.99	4,899.3

¹ Given 10,000 weevil stages.

This table shows a weighted decrease of 3.71 per cent for parasites and a weighted increase of 0.62 per cent for all agencies due to an increase in climatic control.

In the following table is given a comparison of the weighted average control by all agencies for the four years.

TABLE XV.—*Weighted average mortality of the boll weevil, 1906–1909.*

Years.	Weighted average mortality due to—				
	Proliferation.	Climate.	Predation.	Parasites.	All agencies.
1906.....	12.42	24.39	24.85	2.94	64.61
1907.....	12.42	28.16	16.18	3.83	60.61
1908.....	12.42	17.83	11.77	6.34	48.37
1909.....	12.42	23.01	10.92	2.63	48.99
Average.....	12.42	24.45	15.93	3.93	56.73

In view of the fact that certain cotton varieties retain the infested squares more than others, it is interesting to make another hypothesis on the basis that 50 per cent of the infested forms are hanging. The year 1908 is chosen to illustrate this phase of the subject.

TABLE XVI.—*A hypothetical average mortality of the boll weevil in square-retaining varieties.*¹

Class of forms.	Percentage of total number of stages.	Number of stages.	1908. Mortality from—										
			Prolifera- tion.		Remainder.	Climate.		Preda- tors.		Parasites.		Total.	
			Percentage of total.	N u m b e r killed.		Percentage of remainder.	N u m b e r killed.	Percentage of remainder.	N u m b e r killed.	Percentage of remainder.	N u m b e r killed.	Percentage of total.	N u m b e r killed.
Hanging bolls.....	7.50	750	6.3	47.2	702.8	38.48	270.4	3.97	27.9	8.15	57.3	53.7	402.8
Hanging squares.....	42.50	4,250	13.5	573.7	3,676.3	19.24	707.3	9.80	360.3	21.70	797.8	57.3	2,439.1
Total hanging..	50.00	5,000	.....	620.9	4,379.1	.....	977.7	.....	388.2	.....	855.1	.....	2,841.9
Fallen bolls.....	7.50	750	6.3	47.2	702.8	20.08	141.1	5.95	41.8	3.71	26.1	34.1	256.2
Fallen squares.....	42.50	4,250	13.5	573.7	3,676.3	20.30	746.3	15.18	558.1	7.15	262.8	50.3	2,140.9
Total fallen.....	50.00	5,000	.....	620.9	4,379.1	.....	887.4	.....	599.9	.....	288.9	.....	2,397.1
Totals and averages.....	100.00	10,000	.....	1,241.8	.....	18.65	1,865.1	9.88	988.1	11.44	1,144.0	52.39	5,239.0

¹ Given 10,000 weevil stages.

This series of tables, wherein the mortality of the weevil is given an accurate basis for comparison, brings to light some very important points. This is especially the case in Table XVI, which is based upon the hypothesis that 50 per cent of the infested forms are hanging. By comparing this hypothesis for the year 1908 with the table of the same year in which it is considered that only 5 per cent of the forms are hanging, it will be noticed that under the condition of the greatest proportion of hanging squares the total control of the weevil would be 52.39 per cent and the number of parasites to 10,000 weevil stages would be 1,154; whereas, with the smaller proportion of hanging forms, the total control of the weevil would be 48.37 per cent and the total number of parasites 634 to 10,000 weevil stages. Now this shows a gain of 4 per cent in the actual control of the weevil and almost double the number of parasites to 10,000 weevil stages. Naturally, under such conditions it would follow that the parasitic control would be even higher than that which has been used as a basis for the estimate and would increase in rapid proportion. In view of this showing of the fact that the larger the proportion of hanging squares to the entire amount of infested forms, the larger the insect control becomes, we recommend that those who are interested in the breeding of cotton varieties attempt to secure varieties of cotton which will combine the necessary qualities of productiveness, length of lint, and early maturing with the square-retaining tendency. It may be pointed out that the varieties known as Rublee and Cook's Improved are not only conspicuous for the square-retaining qualities but also for their desirability under boll-weevil condi-

tions. Several other varieties have been noticed to have this same tendency, but they have not the other characteristics to recommend them. In this connection we refer the reader to section 4 (p. 21), in which it has been shown that at least two States have had a higher average control of the boll weevil in hanging squares than in fallen squares when all of the records available are considered. It will also be noticed in section 5, under Table XI, giving the actual control of the boll weevil in 1908, that hanging squares and hanging bolls were decidedly in the lead in the total control over either fallen squares or fallen bolls. While this has not been the case in the other years under consideration, we nevertheless consider that the presence of a nursery for the parasites in the field is most desirable. Undoubtedly these hanging squares constitute such a nursery.

6. A STUDY OF HOW AGRICULTURE MODIFIES INSECT CONTROL.

From studies made during 1907 the following comparisons may be made to show the number of factors that it is actually necessary to consider in order that differences in parasitism may be understood.

At Arlington, Tex., records were kept on a field in the red loam post-oak country or "cross timbers," another in the Trinity River bottoms, and a third on the black waxy prairie. The first was planted March 12, the second April 1, the third April 5. On August 28 the weevil infestation of squares in the timbers was 80.5 per cent, in the bottoms 94.3 per cent, and on the prairie 21.4 per cent. At the same time the parasitism in fallen squares on the timbers was 3.12 per cent, in the bottoms 1.9 per cent, and on the prairie 2.56 per cent. In the timbers the parasitism of hanging squares was 39 per cent and in the bottoms 24.78 per cent. The variable factors are soil, flora, time of planting, variety of cotton, and weevil abundance. Hanging squares were found in 1906 to be more highly parasitized in timber land than on the prairie, and fallen squares inversely. There appears to be an indication of the value of early planting. This first field was the earliest field known in the vicinity and it showed a high parasitism in hanging forms throughout the season.

At Calvert, Tex., were two fields on the prairie, one planted March 11 and 12, the other April 1. On June 21 the weevil infestation of the first was 18 per cent and of the second 21 per cent. On July 5 the parasitism in the first was 2 per cent and in the second nothing.

At Denison, Tex., were two fields, one in the red clay, the other on sandy loam, neither surrounded by timber. On the first the stalks were burned February 28, on the second March 15. Both were planted March 30. On August 27 the weevil infestation on the first was 88.3 per cent, on the second 87.6 per cent; the parasitism in fallen squares on the first was 6.31 per cent, on the second 2.85 per

cent; the parasitism in hanging squares on the first was 5.79 per cent, on the second 11.53 per cent. Here the only variable conditions were soil, possibly weeds, and time of plant destruction. The parasitism in the two classes of forms was diametrically reversed.

At Terrell, Tex., were two fields on the sandy prairie, both planted in March, but having different weeds present. The weevil infestation August 26 on one was 65.2 per cent, on the other 97.5 per cent, while the parasitism in hanging squares on the first was 29.5 per cent and on the second 25.6 per cent. The variables were field surroundings and weevil abundance.

The unknown influence which entered most of these examples was very probably the relative abundance of the different species of parasites. This may best be illustrated by the hanging squares from the timbers and bottoms at Arlington, which are quoted above. In the timbers the determinable parasites proved to be 16 *Eurytoma tylodermatis*, 10 *Microbracon mellitor*, 6 *Cerambycobius cyaniceps*, 5 *Microdontomerus anthonomi*, and 3 *Catolaccus* spp. In the bottoms there were 17 *Cerambycobius cyaniceps*, 13 *Microdontomerus anthonomi*, 10 *Eurytoma tylodermatis*, 8 *Catolaccus* spp., and 7 *Microbracon mellitor*. The rank of the species was almost entirely reversed.

Probably the most important point in the entire set of examples is that the earliest crop had the most parasites. To show this in another way we may refer to the conditions on the experimental farm at Dallas. The first part of the field to put on squares was the first part to show parasites. On July 8 infested squares were to be found in six plats, but only on this earliest plat was there any parasitism—5.7 per cent. On July 19 it and the adjacent plat were still considerably in the lead.

That the earliest field should show the highest parasitism was expected by the writers in view of the early spring observations. The parasites in hibernation, whether on the boll weevil or on winter cohosts, all reached maturity in the latter half of March at Dallas. It was reasoned that cotton, squaring and attacked by April 15, would get the hibernated parasites in any part of the State; that cotton squaring and attacked by May 15 would get the first generation of parasites from the cohosts, and so on. It is reasonable to expect that cotton with squares infested in season to attract hibernated parasites or a new brood from cohosts will fare better than cotton that commences squaring when all the parasites are concentrated upon neighboring cohosts. This cotton must wait until the period of the favored cohosts begins to wane before the parasites will begin to seek new scenes of activity. Although it was so reasoned, it was hardly expected that there would be sufficient proof to warrant voicing the proposition.

A series of examinations was made in the vicinity of Victoria, Tex., in 1907 and 1908. On October 9, 1907, Mr. Cushman noted that fall destruction of the cotton was being carried on quite extensively, but in different manners. On the east side of the river, south and east of town, was an area in which practically all of the cotton had been defoliated by the cotton leaf-worm. This area was separated by the river and by a wide strip of huisache timber from other cotton areas. In other directions were located fields stripped by grazing, some that were plowed under, and one field only was found which had received no treatment.

On June 17, 18, and 19, 1908, fallen squares from several of these fields were examined, with the following results:

TABLE XVII.—*Boll-weevil mortality in various cotton fields, Victoria, Tex., 1908.*

Treatment, 1907.	Total stages.	Total.	Percentage of mortality, 1908.		
			Climate.	Predators.	Parasites.
Destroyed stalks, September.....	314	18.18	5.43	4.14	9.23
Plowed, October.....	296	13.80	7.70	3.00	3.00
Plowed, December.....	354	60.70	14.40	41.20	5.08
Grazed, October.....	144	44.40	24.30	15.97	4.16
Do.....	290	37.50	25.50	7.20	4.80
Defoliated.....	480	29.30	20.60	2.50	6.20
Do.....	513	52.80	27.00	11.10	14.40
Do.....	375	23.70	16.50	3.10	4.50

These striking differences in the percentage of control can not be attributed to the differences of treatment in 1907, although that may have had a bearing. The different fields had different weeds and plants surrounding them, they received different treatment in the spring of 1908, and there are many other reasons why no one basis of comparison can be chosen. The table is offered to illustrate how wide a difference in natural control can be found in fields only a few miles apart and proves conclusively the value of individual effort in the fight against the weevil.

Numerous other instances are contained in the notes that are quite as striking as the one to which reference has been made. There is every reason why each planter should follow out as complete a program against the weevil as he can, because each effort reduces the total infestation of his neighborhood.

7. CLIMATIC CONSIDERATIONS.

The climate of the hibernating season of 1906-7 was very unusual, so much so that the boll weevil hardly became quiescent, and the emergence was largely during March, whereas normally it is in April. The boll-weevil parasites mature simultaneously with the

great wave of boll-weevil emergence. A glance at the accompanying diagrams (figs. 4, 5) will show that in Louisiana the monthly mean temperature was from 3° Fahrenheit (November) to 10° (January) higher than the normal, and in Texas it varied from normal (November) to 10° above normal (March) during the entire winter. On the other hand, the accumulated moisture from November 1, 1906, to March 1, 1907, in Louisiana was 5 inches below normal and in Texas 1 inch below normal.

Cotton was planted in March and April (1907) and normally would have squared in May and June, but it was retarded a month by the low temperature in April and May, during which months the monthly mean temperature was 2° to 3° below normal in Louisiana and 3° to 6° below normal in Texas. In addition to the cold of the spring, the precipitation in Louisiana from March 1 to July 1 was 7 inches above the normal and in Texas 2 inches above. This cold and the presence of volunteer cotton tided the boll weevil over until the planted cotton was up. The parasites were obliged to seek cohosts from March 15 until late in May or in June. The cold, damp weather undoubtedly retarded their development so that the first generation was ready to attack such boll weevils as were breeding late in May and early in June. As only a few fields held this advantage to the parasites, these fields naturally became much better stocked with parasites, as has been pointed out in another paragraph.

The summer and early fall months showed a slight deficiency in rainfall and a slightly higher mean temperature—to such an extent, however, that the season was considered dry, for the cotton did not put on a very luxuriant foliage, and thus gave the sun plenty of play on the fallen squares. The result is evidenced by the high percentage of mortality from heat shown in the mortality tables. The increase in parasitism may be ascribed to the same cause.

The mean temperature of October, 1907, was normal in Texas, but 10° above normal in Louisiana. This warm season was followed by a very sudden drop in temperature on November 11, the “norther” lasting until the 15th. This caused the November mean in both States to be 3° below normal (Texas 53° F., Louisiana 56° F.). In both States during this one month the precipitation was 3 inches above the normal. In northern Texas about 30 per cent of the adult weevils were killed by cold. The temperature at Dallas¹ reached 14° on November 13, which was 11° colder than was experienced in 1906 and 21° lower than at any time in November, 1905. The boll weevils were not prepared for this cold, as they were still in great

¹ The record was made both by the minimum thermometer and the self-registering thermograph at the laboratory in East Dallas, and is a few degrees lower than the official record at Oak Cliff, about 5 miles to the west and across the Trinity River.

numbers on the plants and many immature stages were developing in green squares and bolls.

Table XVIII gives the results of the examinations made immediately after the freeze.

TABLE XVIII.—*Mortality of the boll weevil in Texas, November, 1907.*

Place.	Date.	Form.	Location.	Condi- tion.	Stages.	Mortal- ity.	Mortality due to—		
							Cold.	Para- sites.	Other causes.
	1907.					<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Dallas.....	Nov. 14	Squares...	Fallen...	Green...	93	97.7	96.7	1.0	
Do.....	do.	do.....	do.....	Dry.....	151	47.0	36.4	5.9	4.6
Brownwood.....	Nov. 15	do.....	Plant...	Green...	2	100.0	100.0		
Navasota.....	Nov. 19	do.....	do.....	do.....	(1)	100.0	100.0		
Calvert.....	Nov. 20	do.....	do.....	do.....	(1)	100.0	100.0		
Dallas.....	Nov. 14	Bolls.....	Fallen...	Dry.....	13	30.7	7.6	7.6	15.3
Do.....	do.	do.....	Plant...	do.....	8	37.5			37.5
Brownwood.....	Nov. 15	do.....	do.....	Green...	7	100.0	100.0		
Navasota.....	Nov. 19	do.....	do.....	Mixed...	56	96.3	57.1	3.5	35.7
Calvert.....	Nov. 20	do.....	do.....	do.....	21	95.2	38.0		57.2
Waco.....	Nov. 21	do.....	do.....	do.....	16	100.0	50.0		50.0
Hillsboro.....	do.	do.....	do.....	do.....	27	100.0	63.0		37.0
Totals and averages.		(Squares			246	66.3	59.8	4.0	2.8
		Bolls.....			148	88.5	49.3	2.0	237.1
Totals and averages.					394	74.3	55.3	3.2	15.8

¹ Several.

² Most of the death from "other causes" in bolls was due to proliferation, which seems to be stimulated by frosts.

From this small number of stages no general statement can be made. Of the 394 stages 55.3 per cent were killed by cold. Of the stages in green squares or bolls, 98 per cent were killed by the cold.

The most interesting point is that although 98 out of 100 weevil stages in green forms were killed, a parasite larva was found to have just hatched from its egg on a weevil larva killed by cold. Three other similar cases were found in dry forms. Seventeen cases of parasitism were found on the 394 stages. Among these were two living eggs of which one was an entirely new type and also two pupæ which proved to be *Habrocytus piercei*.

The remainder of the winter of 1907-8 that is, from December to March 1—had a mean temperature a few degrees above the normal, but with several severe cold spells. During the four winter months the precipitation in both States was above the normal. The short cold spells with warmer intervening weather and heavier rainfall were disastrous to the boll weevil. The February examination to ascertain the mortality of the weevil indicated about 98 per cent mortality. As a result of the extreme scarcity of weevils in the spring and summer in most parts of Texas, there was a great reduction in the number of parasites. In fact, in the northern portion of the Texas black prairie the parasites were forced to seek other hosts. A killing freeze in November, 1908, again killed many boll weevils.

Following the cold of November, 1908, the winter was unusually warm, being at least 5° F. above the normal in both Louisiana and Texas. From March 15 to July 15, in both States, the temperature was almost normal. However, by this time there was an accumulated deficiency of precipitation in each State of several inches. The months of July and August in Texas were extremely warm and many places recorded the maximum temperatures for their entire period of records. While the heat was less excessive in Louisiana, it nevertheless reached very high points. This extreme weather during these two months had a tremendous effect upon the boll weevil and upon its parasites, although records taken after some of the hottest days showed that the mortality of the boll weevil from the heat was considerably higher than the mortality of the parasites of the boll weevil. After the middle of August a period of renewed growth of the cotton plant gave the boll weevil an opportunity for increased development and consequently permitted a large number of weevils to mature before the hibernation season. Incidentally with this fall brood of weevils, we find that there was a very great increase in the parasites, especially in Louisiana. The following two diagrams (figs. 4, 5) illustrate the temperature of the years under consideration.

8. HOW INSECT CONTROL FOLLOWS THE DISPERSION OF THE BOLL WEEVIL.

From an economic standpoint it is very important to know what kind of natural control of the boll weevil can be expected in newly invaded country. Since 1904 it has been noticed that maximum infestation is generally reached by August 1, and that simultaneously an extensive dispersion of the boll weevil takes place. At this period the boll weevils fly to fields many miles beyond the parasites. The climatic conditions during the dispersion period are such as will not seriously interfere with prolific breeding of the weevils in the newly infested territory. The extent of the dispersion is limited only by the number of weevils flying and the amount of food supply available. In the fall of 1909 the sparse production of cotton in southern Mississippi brought about a dispersion of 120 miles into new territory.

Our knowledge of the insects which attack the boll weevil shows that most of them are derived from the parasites of similar weevils that are native to the region infested. Therefore, if parasites and predators are present in the invaded region, it is reasonable to expect that they will immediately begin attacking the boll weevil. This assumption has been proven in many definite cases. At Minden, La., in 1906, a parasite larva was found in a green square infested by the first generation. At Roxie, Miss., where the weevils had been present only a few weeks in September, 1908, ant work and parasite work

were easily found. Later in the season of 1908, an isolated infestation was found at Roadside, in Yazoo County, Miss., about 40 miles beyond

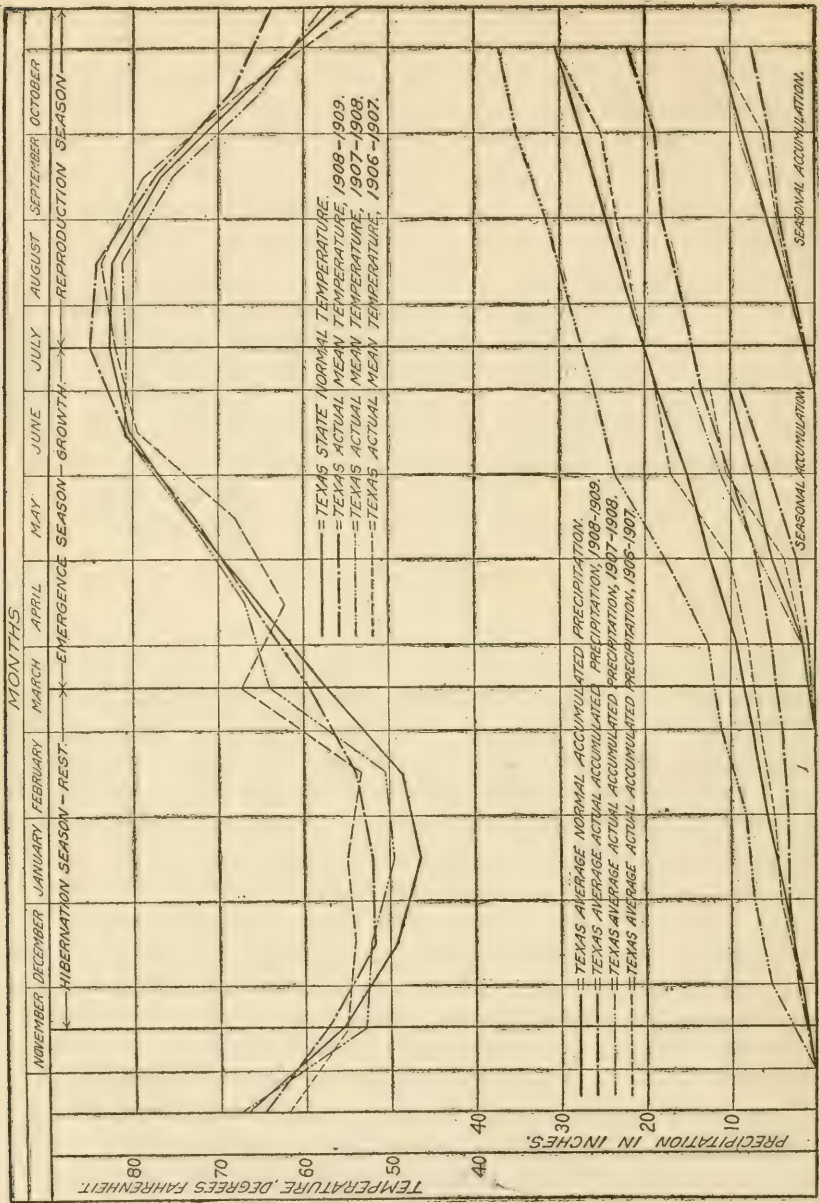


Fig. 4.—Diagram illustrating Texas climatic variations in 1907, 1908, and 1909. (Original.)

the regular line of infestation, but it was noticeable that the weevil was parasitized in this particular field.

9. THE STATUS OF THE BOLL WEEVIL AND ITS CONTROL BY INSECTS.

During the seasons of 1908 and 1909 the examinations of the boll weevil to determine its status demonstrated that there had been a

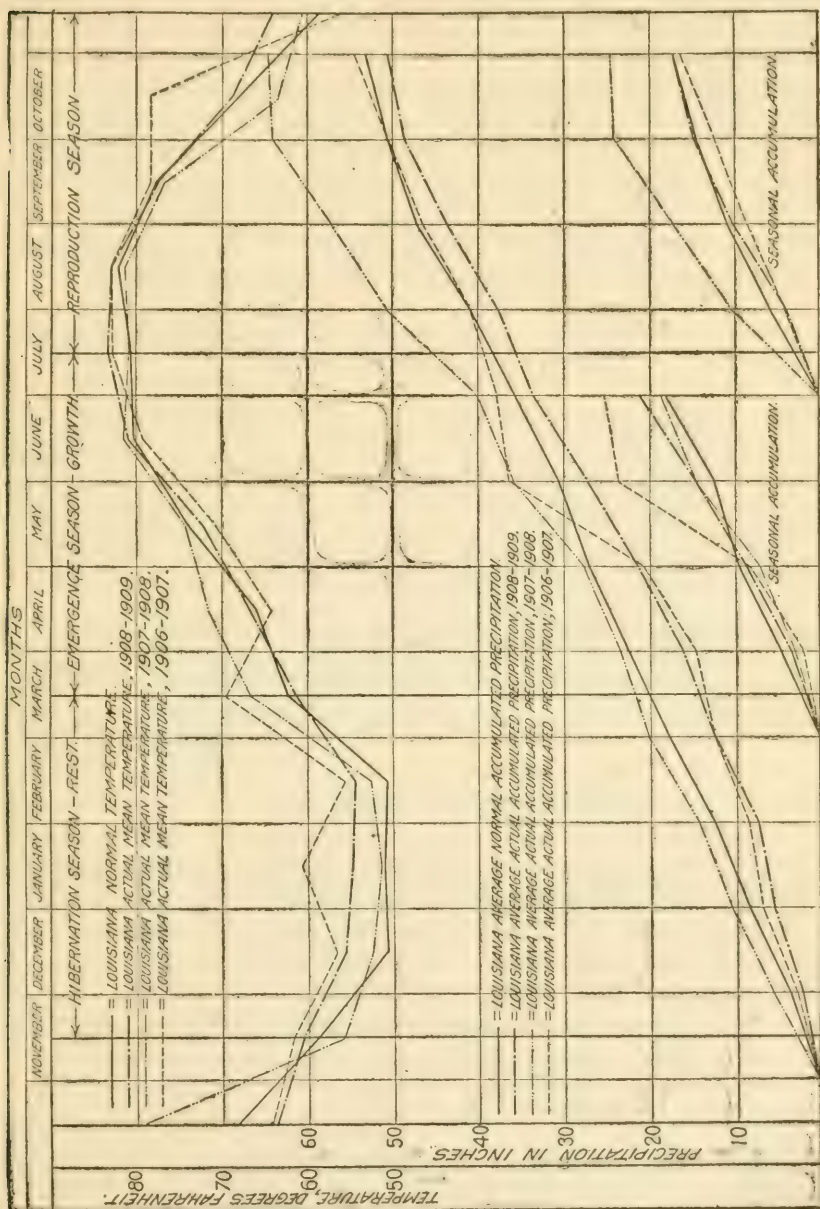


FIG. 5.—Diagram illustrating Louisiana climatic variations in 1907, 1908, and 1909. (Original.)

tremendous falling off of the weevil in all western and northern Texas. In August, 1909, there was less than 10 per cent infestation in half of

Texas and in all of Oklahoma. At the same time a maximum infestation was found in all of that part of Louisiana lying south of the Red River and in Mississippi for about 20 miles east of Natchez. An analysis of the parasite records for this same season shows that the parasite control of the weevil in these sparsely infested regions of Texas was very light, whereas the control in the heavily infested regions of southern Louisiana and Mississippi was correspondingly very high. The inference drawn from this observation is either that the boll weevil had ceased to be the predominating weevil species for parasitic attack in the lightly infested region, or that the parasites had been destroyed by the heat. That the parasites were not all destroyed by the heat is demonstrated by many records of the same parasites on other species of weevils during the fall and winter of 1909.

10. A BRIEF STATEMENT OF THE VARIOUS CLASSES OF CONTROL EXERCISED UPON THE BOLL WEEVIL.

Before passing from this part of the report, which deals with the general conditions obtaining, it is necessary to say a few words concerning the classes of control which are of importance in repressing the boll weevil. The first agency which is responsible for mortality of the weevils is the resistance of the cotton plant to attack, evidenced either by the toughness of the plant tissues which must be punctured, or by the proliferation of the tissues, which destroys the weevil eggs and larvæ by crushing. When the infested form falls to the ground or withers on the plant it becomes immediately a subject for numerous other factors of control. Intense heat kills many stages. A large number of parasite species seek out infested squares for their progeny; myriads of ants, beetles, and mites find nourishing food by merely cutting their way into the infested forms and devouring the weevil stages. In addition to these, sudden cold freezes countless numbers of developing weevils. Neither are adults free from adverse conditions. Many are killed by heat, or cold, or drowning; many are picked up by birds and lizards or preyed upon by other insects; and finally multitudes are starved on account of the ravages of other insects upon their food supply. In this report we are able to deal only with the three factors which are determinable in the control of immature weevils, namely, climate, parasites, and predators.

11. PRACTICAL CONCLUSIONS DERIVED FROM STATISTICAL STUDIES.

The following conclusions of economic importance have been reached from a study of this large series of statistics:

- I. The month of August is the most important month for the control of the weevil by insect enemies. As this month is also the most

important in the control affected by climate, it should be considered as one of the most critical times of the year for controlling the boll weevil. When a sudden drop in the temperature below freezing occurs in the month of November before a large proportion of the weevils has entered hibernation, and while many are still immature, an excellent control of the species can be obtained. As, however, this is only an occasional occurrence, it can not be relied upon and every measure possible should have been carried out to prevent the weevils from going into hibernation at all.

II. Hanging squares are the most important infested parts for the work of parasites, and fallen squares in a similar degree for the work of the predatory enemies. It has been demonstrated also that in certain years the total control by all agencies is greater in hanging squares than in fallen squares, and furthermore that in the more humid States this condition is the prevalent one.

III. It has been shown by examples that the total mortality of the weevil can be increased in proportion as the number of hanging squares in a given area is increased and likewise that the proportion of parasites to weevils is increased. It is therefore recommended that plant breeders attempt to develop varieties of cotton which will retain the squares, but will also have the other desirable varietal characteristics necessary for the production of an early cotton crop.

IV. The insect control of the boll weevil is dependent in a large measure upon the operations of the farm and for this reason all those field practices which have been included in the system of cultural control of the boll weevil are further recommended as tending to increase the insect control.

PART II. BIOLOGICAL COMPLEX.

In Part I of this bulletin one set of facts, composed of statistics, was dealt with, and it was merely hinted that the causes of these conditions were very complex. In this part is presented another series of facts, even more significant than the first, but much more difficult to present in a tangible manner. The study of these biological factors received its first impetus when at Clarendon, Tex., in 1905, Mr. C. R. Jones and the senior author were fortunate enough to learn the biologies of three species of weevils and to find that all these were parasitized more or less abundantly by the same parasites as is the boll weevil. It was already known that some of the parasites of the boll weevil attacked other weevils, but the significance of this fact had not been realized.

With this simple beginning the search for other hosts of the boll-weevil parasites was started and we have now built up the knowledge of the following complex:

Owing to the complicated nature of the data to be presented in this part, these have also been arranged in the following sections:

1. A list of the insect enemies of the boll weevil.
2. The hosts of boll-weevil parasites.
3. Mites which attack the boll weevil.
4. Flies which parasitize the boll weevil.
5. The hymenopterous parasites of the boll weevil.
6. Biological notes upon the parasites of the boll weevil.
7. The development of the parasites.
8. The distribution of the parasites.
9. The parasite seasons.
10. Adjustment to new hosts.
11. Beetles which prey upon the boll weevil.
12. Lepidopterous larvæ which are incidentally predatory upon the boll weevil.
13. Ants which prey upon the boll weevil.
14. Biology of the cohosts of the boll-weevil parasites.
15. A list of the host plants of the cohost weevils.
16. A summary of the most important biological facts.

1. A LIST OF THE INSECT ENEMIES OF THE COTTON BOLL WEEVIL.

The boll weevil is known to be attacked by 29 species of parasites, while 20 species of predators attack the immature stages and 6 species of predators attack the adults. These species are listed as follows:

Arachnida.

Acarina. Sarcoptoidea.

Tarsonemidæ. Pediculoidinæ.

Pediculoides ventricosus Newport (parasite on larva), Mexico.

Pediculoides sp. (parasite on larva), Louisiana, Texas.

Tyroglyphidæ.

Tyroglyphus breviceps Banks (parasite on larva), Texas.

Insecta.

Orthoptera. Mantoidea.

Mantidæ.

Stagmomantis limbata Hahn (predator on adult), Texas.

Hemiptera-Heteroptera.

Reduviidæ.

Apiomerus spissipes Say (predator on adult), Texas.

Coleoptera. Adephaga.

Carabidæ.

Evarthrus sodalis Le Conte (predator on adult), Louisiana, Texas.

Evarthrus sp. (predator on adult), Louisiana.

Insecta—Continued.

Coleoptera. Polyphaga. Diversicornia.

Cantharidæ.

Chauliognathus spp. (predators on larva), Louisiana, Mississippi.

Cleridæ.

Hydnocera pallipennis Say (predator on larva), Texas.

Hydnocera pubescens Le Conte (predator on larva), Texas.

Cucujidæ.

Cathartus cassiæ Reiche (predator on larva), Texas.

Lepidoptera. Bombycoidea.

Noctuidæ.

Alabama argillacea Hübner (defoliator, cuts off food supply).

Hymenoptera. Formicoidea.¹

Dorylidæ.

Eciton (Acamatus) commutatum Emery (predator on larva), Texas.

Poneridæ.

Ectatomma tuberculatum Olivier (predator on adult) Guatemala.

Myrmicidæ. Cremastogasterinæ.

Cremastogaster lincolata (Say) var. *clara* Mayr (predator on larva) Texas.

Myrmicidæ. Solenopsidinae.

Solenopsis geminata (Fabricius) var. *diabola* Wheeler (predator on larva), Louisiana, Mississippi, Texas.

Solenopsis molesta Say (= *debilis* Mayr) (predator on larva), Oklahoma.

Solenopsis texana Emery (predator on larva), Louisiana, Texas.

Myrmicidæ. Myrmicinae.

Monomorium minimum Buckley (predator on larva), Louisiana, Mississippi, Texas.

Monomorium pharaonis Linnaeus (predator on larva), Arkansas, Louisiana, Oklahoma, Texas.

Pheidole sp. near *flavens* (predator on larva), Texas.

Pheidole crassicornis Emery (predator on larva), Texas.

Dolichoderidæ.

Forelius maccooki Forel (predator on larva), Texas.

Dorymyrmex pyramicus Roger (predator), Cuba.

Dorymyrmex pyramicus (Roger) var. *flavus* McCook (predator on larva), Texas.

Iridomyrmex analis André (predator on larva), Texas.

Formicidæ.

Formica fusca subpolita perpilosa Wheeler (predator on adult), Mexico.

Formica pallidi-fulva Latreille (predator on larva), Arkansas.

Prenolepis imparis Say (predator on larva), Arkansas.

Hymenoptera. Chalcidoidea.

Chalcididæ. Chalcidinae. Smicrini.

Spilochalcis sp. (parasite), Texas.

Torymidæ. Monodontomerinae.

Microdontomerus anthonomi Crawford (parasite), Louisiana, Texas.

Eurytomidæ.

Eurytoma tylosidermatis Ashmead (parasite), Arkansas, Louisiana, Mexico, Oklahoma, Texas.

Bruchophagus herrerae Ashmead (parasite), Mexico.

Eurytoma sp. (parasite), Texas.

¹ All of these ants have been determined by Prof. William Morton Wheeler.

Insecta—Continued.

Hymenoptera. Chalcidoidea—Continued.

Perilampidæ.

Perilampus sp.¹ (parasite), Louisiana.

Encyrtidæ. Eupelminæ.

Cerambycobius cyaniceps Ashmead (parasite), Arkansas, Louisiana, Mississippi, Oklahoma, Texas.

Cerambycobius cushmani Crawford (parasite), Texas.

Cerambycobius sp. (parasite), Mississippi.

Pteromalidæ. Pteromalinæ.

Catolaccus incertus Ashmead (parasite), United States.

Catolaccus hunteri Crawford (parasite), Louisiana, Mississippi, Mexico, Texas.

Habrocytus piercei Crawford, Louisiana, Texas.

Lariophagus texanus Crawford (parasite), Texas.

Eulophidæ. Tetrastichinæ.

Tetrastichus hunteri Crawford (parasite), Louisiana, Mississippi, Texas.

Hymenoptera. Ichneumonoidea.

Ichneumonidæ. Pimplinæ. Pimplini.

Pimpla sp. (parasite), Texas.

Braconidæ. Sigalphinæ.

Sigalphus curculionis Fitch (parasite), Louisiana, Mississippi, Texas.

Urosigalphus anthonomi Crawford (parasite), Texas.

Urosigalphus schwarzi Crawford (parasite), Guatemala.

Urosigalphus sp. (parasite), Texas.

Braconidæ. Braconinæ. Braconini.

Microbracon mellitor Say (parasite), Mexico, United States.

Braconidæ.

Unknown species (parasite), Texas.

Diptera. Cyclorrhapha.

Phoridæ.

Aphiochæta nigriceps Loew (parasite), Texas.

Aphiochæta fasciata Fallen (parasite), Texas.

Aphiochæta pygmæa Zetterstedt (parasite), Texas.

Tachinidæ.

Myiophasia aenea Wiedemann (determined by Coquillett) (parasite), Texas.

Ennyomma globosa Townsend (parasite), Louisiana, Texas.

HYPERPARASITES.²

Diptera.

Plastophora (Pseudacteon) crawfordi Coquillett on *Solenopsis geminata* Fabricius.

2. THE HOSTS OF BOLL-WEEVIL PARASITES.

As has just been stated, the boll weevil has 55 species of insects, which are known to attack it. Among the parasites are to be found 7 which are occasionally accidentally hyperparasitic. At least 1 parasite is known to attack one of the predators. The accidental predator (*Alabama argillacea*) is attacked by 12 parasites, 46 predators,

¹ This species may be a parasite of a *Chrysopa* larva or of some lepidopteron which had entered a weevil cell.

² The enemies of *Alabama argillacea* Hübner afford some interesting sidelights on the complexity of the biological relations of cotton insects.

and 1 hyperparasite. Among these 46 predators are 6 which also prey upon the boll weevil. At least 1 very common predatory insect is known to prey upon many of the boll-weevil predators. Fifty-five species of weevils are known to be attacked as cohosts of 26 species of parasites and of the 19 species of predators which attack the boll weevil. These 55 species of weevils are known to breed upon 91 species of plants, most of which are to be found in the vicinity of the cotton fields. Three of these weevils sometimes breed upon the cotton plant. Among the great number of parasites which attack the 55 cohost weevils, 44 species are definitely known to science and at least 6 species of hymenopterous parasites are known to attack these 44 species of parasites. This complexity could be carried still further, but probably enough has been stated to show how the many influences of nature are dependent upon one another. The statements are illustrated graphically in the accompanying diagram (fig. 6).

The principal point of importance in all of these facts is that the boll weevil has been deriving its parasites from these 51 species of weevils and from other weevils which are not known to us, and there is every reason to believe that some of these other 44 species of parasites, or still additional ones to be discovered, may be drawn over to the boll weevil as parasites in the future. The weevils serving as cohosts and the parasites are listed in the accompanying table (fig. 7) in such manner as to show the nature of the interrelationships.

It will be noticed from this table that 6 weevils, namely, *Larisa sallæi*, *Larisa exigua*, *Smicraulax tuberculatus*, *Anthonomus albopilosus*, *Tyloderma foveolatum*, and *Trichobaris texana* each have 4 of the boll-weevil parasites; 4 weevils are attacked by 3 of the parasites, 15 of the weevils by 2 parasites each, and the remaining 37 by only 1 parasite each.

Of the parasites, *Cerambycobius cyaniceps* attacks 18 hosts, *Eurytoma tylodermatis* attacks 16 hosts, *Catolaccus incertus* 14, *Catolaccus hunteri* 13, and *Microbracon mellitor* 12. These 5 parasites are also regarded as the most important parasites attacking the boll weevil itself. Perhaps this importance is due to the fact that they have a larger number of native hosts and are hence in greater abundance around the cotton fields than the parasites having fewer native hosts.

3. MITES WHICH ATTACK THE BOLL WEEVIL.

ACARINA. TARSONEMIDÆ.

The mites of the genus *Pediculoides* are assuming an important rôle among insect parasites, two species being accredited to the boll weevil.

Pediculoides ventricosus Newport (fig. 8). This mite has been somewhat prominent in the study of the boll weevil since its first notice in 1901 (Rangel, 1901) under the name of *Pediculoides ven-*

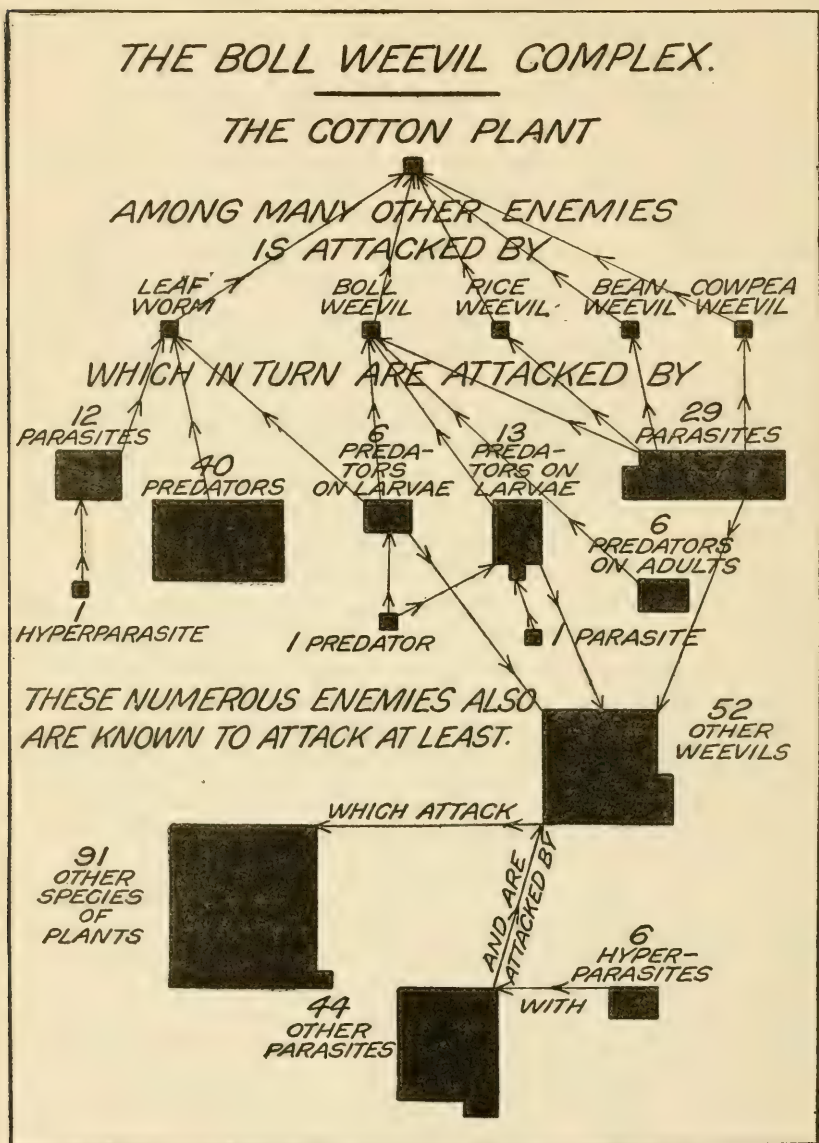


FIG. 6.—Diagram illustrating the boll-weevil complex. (Original.)

triculosus. Mr. Banks has stated that it may possibly be different from the European species, but as it is known throughout this country under the above name it is so quoted here. Mr. Rangel

pointed out that these mites reproduce viviparously and that their offspring are mature and fertile at birth. He found that when they attach themselves to a host the abdomen commences to inflate until it becomes many times larger than the thorax. The time required for engorgement varies from 2 to 5 days. When the abdomen commences to grow, the young commence to leave the parent. The males fertilize the females before leaving the parent's body and shortly afterwards die. An average of 100 female offspring to an individual was recorded. Rangel found that in 48 hours, 21 stages out of 40 in squares were attacked by the mites. In larger series of tests, after four days 50 out of 153 weevil stages in squares were attacked, or 32.6 per cent.

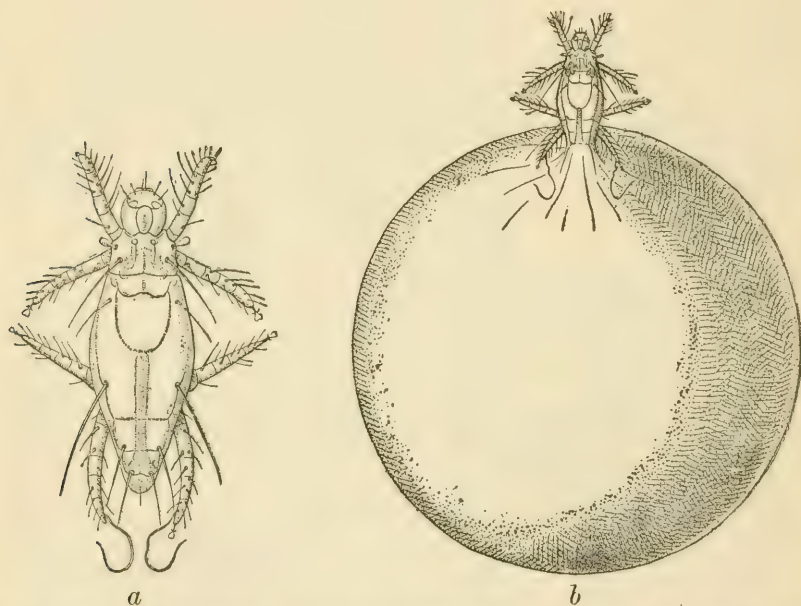


FIG. 8.—*Pediculoides ventricosus*: a, Adult female before inflation of abdomen with eggs and young; b, adult female after inflation of abdomen with eggs and young. Greatly enlarged. (Redrawn from Brucker.)

Pediculoides n. sp. This mite was discovered in the laboratory at Dallas, Tex., June 13, 1907, by the senior author. Careful observations on the length of generations were made with the following results: A gravid female was isolated June 13 and on June 17 there were 31 gravid mites. All but 5 were removed. On June 19 there were many offspring, one mite being well grown. On June 21 the fourth generation began to appear. In other words, between June 13 and June 21, that is, in less than 8 days, there were two complete generations. Another genealogy was as follows: Parent isolated June 13, second generation began to appear June 14, were mature

June 17, and reproducing June 19. On June 24 the third generation was reproducing. In this case there were 11 days covering two complete generations.

The mites appeared willing to feed on any insect food available, as they were first found feeding on stages of *Trichobaris compacta*, then on boll-weevil stages, and finally on a *Baris*, on boll-weevil parasites isolated in rearing tubes, and on *Hydnocera pubescens*. They were reared readily on larvæ of *Chlorion cyaneum* and *Polistes rubiginosus*. Mr. John B. Railsback, of Forbing, La., found that they attacked the larvæ of the bollworm and other smooth caterpillars very readily.

TYROGLYPHIDÆ.

Tyroglyphus breviceps Banks was described as a weevil enemy from Victoria, Tex. This, or a similar mite, was found to be very abundant at Calvert, Tex., in 1906.

4. FLIES WHICH PARASITIZE THE BOLL WEEVIL.

Very few Diptera are known to be primarily parasitic upon boll weevils, but the genera *Myiophasia* and *Ennyomma* in the Tachinidæ seem to be confined to hosts of this nature. The genus *Aphiochæta*, of the Phoridæ, contains at least 3 species which have been reared under circumstances pointing to primary parasitism. The larvæ of the tachinids work singly and those of *Aphiochæta* several to a host, but in both cases as endoparasites. When the former become full grown they completely fill the skins of the weevil larvæ and frequently the appendages of *Myiophasia* penetrate to the exterior. The weevil skin partakes of the character of parchment and becomes a cocoon within which the fly larva pupates and from which the adult emerges. On the contrary the *Aphiochæta* larvæ leave the host when they have reduced it to a shell and pupate in the weevil cell.

The flies evidently prefer to attack weevil stages in moist, shaded spots in preference to sunny locations. By this habit they become very valuable in fields located in bottom lands where the dry conditions conducive to parasites like the hymenopterous parasites are absent. The puparia of *Myiophasia* and *Ennyomma* are so near like that of the chalcidoid internal parasite *Tetrastichus hunteri* that they can be differentiated only by the larger size of the dipterous puparia.

PHORIDÆ.

Aphiochæta nigriceps Loew (determined by D. W. Coquillett).

Aphiochæta fasciata Fallen (determined by D. W. Coquillett).

Aphiochæta pygmæa Zetterstedt (determined by D. W. Coquillett).

On September 12, 1906, in dry hanging bolls collected at Dallas, Tex., a weevil larva was found parasitized and isolated in a separate tube, with the following record: "Very small parasite larva on small weevil larva." On September 26 a single specimen of *Aphiochæta nigriceps* Loew was reared and the following note made by the senior author: "Found dipterous puparium, skin of hairy parasite larva (may be the dipteran or a hymenopteron); also remains of weevil larva." On October 6, 1906, in hanging bolls collected at Dallas a weevil larva was isolated with the note, "Weevil larva full of dipterous larvæ." Eleven larvæ left this host larva and pupated. On October 29, 7 *Aphiochæta* (?) *fasciata* Fallen and two *A. pygmæa* Zetterstedt were reared. At least the latter case seems to be very strong evidence of primary parasitism. These flies are reared frequently from bolls and many are perhaps scavengers. Two other species, *A. epciræ* Brues and *A. scalaris* Loew, have also been reared from cotton forms at Calvert, Tex. Records made in 1911, at Talulah, La., by Mr. Harry Pinkus, point conclusively to primary parasitism.

TACHINIDÆ.

Myiophasia ænea Wiedemann is recorded from a number of very important weevils. Of these, *Balaninus nasicus* Say (the acorn weevil), *Conotrachelus juglandis* LeConte (the walnut weevil), *Ampelogypter sesostris* LeConte (the grapevine gall-maker), *Conotrachelus affinis* Boheman (the hickory-nut weevil), and *Conotrachelus elegans* Say (the pecan-gall weevil) are all weevils which enter the ground for pupation, carrying their parasites with them, and consequently it becomes necessary for the flies to emerge from the weevil cell through several inches of earth before attaining freedom. The only weevils which this fly attacks and which do not enter the ground for pupation are the boll weevil and *Trichobaris compacta* Casey (the Jamestown-weed pod weevil). Very few records have been made to ascertain its developmental period, but the three records at hand indicate from 22 to 29 days as the period from collection of the infested material to the maturity of the fly. This period would cover largely the underground period only.

Ennyomma (*Loewia*) *globosa* Townsend. Several specimens of this fly were reared during 1907 by Mr. C. R. Jones at Alexandria, La., as primary parasites of the boll weevil. It is a very common parasite of *Chalcodermus æneus* Boheman (the cowpea-pod weevil) in the Southern States.

5. THE HYMENOPTEROUS PARASITES OF THE BOLL WEEVIL.

So much information has been gained concerning the hymenopterous parasites of the boll weevil that it will be necessary to omit many of the technical facts learned about them. The present sec-

tion is concerned with the sources of the parasites and with important records of their occurrence, while the other interesting facts to be presented are included in the five following sections:

CHALCIDOIDEA. CHALCIDIDÆ. CHALCIDINÆ. SMICRINI.

Spilochalcis sp. A single male of this species was found dead in a weevil cell with the remains of the weevil and its own exuvium in a hanging square collected August 10, 1907, at Victoria, Tex.

TORYMIDÆ. MONODONTOMERINÆ.

Microdontomerus anthonomi Crawford (fig. 9). *Brachytarsus alternatus* Say was formerly the only weevil recorded as a host of this species. A male and female of this parasite were reared on Septem-

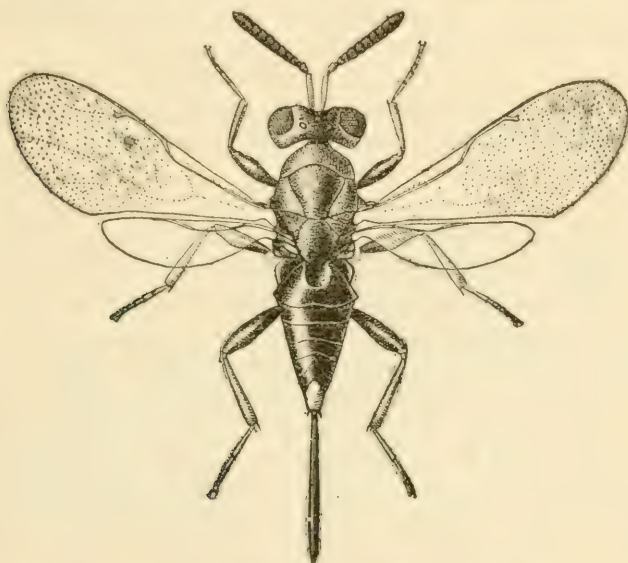


FIG. 9.—*Microdontomerus anthonomi*: Adult. Much enlarged. (Original.)

ber 12, 1907, from pods of the flowering shrub *Amorpha fruticosa*, at Dallas, Tex., which were highly infested by (*Bruchus*) *Laria exigua* Horn. In 1906, in which year this parasite was first discovered, it ranked as seventh species in importance as a boll-weevil enemy. In 1907 it advanced to fourth place and was very important in the central black-prairie region of Texas. In 1909 the easternmost limit of our records was Tallulah, La., which did not become infested by the boll weevil until 1908.

EURYTOMIDÆ. EURYTOMINI.

Eurytoma tylodermatis Ashmead (*Bruchophagus herrerae* Ashmead). This is without doubt one of the most important species under consideration, having a range of distribution practically coexten-

sive with that of its host, the boll weevil. In previous publications it has been recorded as a parasite of *Lixus musculus* Say, *L. scrobicollis* Boheman, *Apion segnipes* Say, *Anthonomus heterothecæ* Pierce, *Anthonomus squamosus* LeConte, *Tyloderma foveolatum* Say, and *Orthoris crotchii* LeConte. To this list may be added (*Bruchus*) *Laria exigua* Horn in *Amorpha* pods at Dallas, Tex.; (*Bruchus*) *Laria sallæi* Sharp in pods of huisache (*Vachellia farnesiana*) collected at Victoria, Tex.; *Spermophagus robinix* Schönherr in pods of the honey and water locusts (*Gleditsia triacanthos* and *G. aquatica*) in Louisiana; *Macrorhoptus sphæralciæ* Pierce in pods of *Sphæralcia* at Del Rio, Tex.; *Smicraulax tuberculatus* Pierce in mistletoe stems at Dallas, Tex.; *Trichobaris texana* LeConte in stems of *Solanum rostratum* at Cisco and Victoria, Tex.; and also *Trichobaris trinotata* Say; and finally it was reared in September, 1908, from *Baris* sp. in roots of ambrosia at Camden, Ark., by C. E. Hood.

Eurytoma sp. A female primary parasite and a male accidentally secondary on *Microbracon mellitor* Say were reared from hanging squares collected August 10, 1907, at Victoria, Tex.

PERILAMPIDÆ.

Perilampus sp. A single individual was reared from the boll weevil in an isolated weevil cell by C. E. Hood from squares collected September 7, 1907, at Shreveport, La. Another specimen of *Perilampus* was reared from squares collected at Granbury, Tex., August 8, 1907, but its source could not be proved. If it were not for the definite record made by Mr. Hood these species could hardly be placed in this list. This record may possibly be based upon the parasite of an intruder in the weevil cell instead of upon the weevil itself. It is not impossible that after several years this parasite may be found normally as a boll-weevil parasite, as was the case with *Sigalphus curculionis*.

ENCYRTIDÆ. EUPELMINÆ.

Cerambycobius cyaniceps Ashmead. The list of hosts of this species as previously recorded included *Anthonomus albopilosus* Dietz, (*Bruchus*) *Laria obtecta* Say, *L. exigua* Horn, *Lixus musculus* Say, *Trichobaris texana* LeConte, and *Tyloderma foveolatum* Say. To this list may be added *Laria bisignata* Horn in pods of *Acuan illinoensis*; *L. ochracea* Schaeffer in pods of *Vicia* sp.; *L. sallæi* Sharp in pods of huisache (*Vachellia farnesiana*); *Spermophagus robinix* Schönherr in pods of *Gleditsia triacanthos* at Alexandria, La.; *Lixus scrobicollis* Boheman in stems of *Ambrosia trifida* and *A. psilostachya*; *Apion rostrum* Say in pods of *Baptisia tinctoria* at Washington, D. C.; *Tachypterellus quadrigibbus* Say in fruit of *Cratægus mollis* at Victoria, Tex.; *Smicraulax tuberculatus* Pierce in stems of mistletoe

(*Phoradendron flavescens*); *Tychius sordidus* LeConte in *Baptisia* pods at College Station, Tex.; *Trichobaris compacta* Casey in pods of *Datura stramonium* at Paris, Tex.; and, furthermore, on *Languria* sp. in stems of *Gaura* sp. at Ballinger, Tex.

Cerambycobius cushmani Crawford. This parasite was reared in small numbers as early as 1906 in southern Texas from the boll weevil. It has been reared from *Laria ochracea* Schaeffer in pods of *Vicia* sp.; from *L. sallæi* Sharp in pods of *Vachellia farnesiana*; from *Aræcerus fasciculatus* DeGeer in fruit of chinaberries (*Melia azedarach*) at Victoria, Tex.; and from *Trichobaris texana* in stems of *Solanum rostratum*.

Cerambycobius sp. On February 23, 1909, a male of a green species of *Cerambycobius* was reared from the weevil in squares collected at Natchez, Miss., January 19.

PTEROMALIDÆ. PTEROMALINÆ.

Catolaccus hunteri Crawford. This is the species which in all previous articles on the boll weevil has been known as *Catolaccus incertus*. Its hosts as now known are *Laria compressicornis* Schaeffer in pods of *Acuan illinoensis*; *Tachypterellus quadrigibbus* Say in fruit of *Cratægus* spp.; *Smicraulax tuberculatus* Pierce in stems of *Phoradendron flavescens*; *Anthonomus æneolus* Dietz in buds of *Solanum* spp.; *Anthonomus albopilosus* Dietz in seeds of *Croton* sp.; *Anthonomus eugenii* Cano in fruit of pepper (*Capsicum* spp.); *Anthonomus heterothecæ* Pierce in heads of *Heterotheca subaxillaris*; *Anthonomus nebulosus* Le Conte in buds of *Cratægus* spp.; *Anthonomus signatus* Say in buds of dewberry (*Rubus* spp.); *Anthonomus squamosus* Le Conte in heads of *Grindelia squarrosa nuda*; (*Acalles*) *Gerstæckeria nobilis* Le Conte in joints of *Opuntia* spp.; *Zygobaris xanthoxyli* Pierce in berries of *Xanthoxylum clava-herculis*.

Catolaccus incertus Ashmead. This parasite is also very common and is known from a considerable number of hosts, among which are *Laria exigua* Le Conte in pods of *Amorpha fruticosa*; *Apion decoloratum* Smith in pods of *Meibomia paniculata*; *Apion griseum* Smith in pods of *Phaseolus* spp.; *Apion nigrum* Smith in buds of *Robinia pseudacacia*; *Anthonomus albopilosus* Dietz in seeds of *Croton* spp.; *Anthonomus aphanostephi* Pierce in heads of *Aphanostephus skirrobasis*; *Anthonomus fulvus* Le Conte in buds of *Callirrhoe involucrata*; *Anthonomus nigrinus* Boheman in buds of *Solanum carolinense*; *Anthonomus signatus* Say in buds of strawberry (*Fragaria virginiana*); *Auleutes tenuipes* Dietz in buds of *Galpinsia hartwegi*; *Ceutorhynchus* n. sp. in crown of *Selenia aurea*; *Baris cuneipennis* Casey in roots of *Helenium tenuifolium* and *Calandra oryza* Linnæus in corn

Habrocytus piercei Crawford. This is a brilliant green parasite resembling *Catolaccus anthonomi* Ashmead. It is reared from the boll weevil mainly in the fall and from hibernated individuals in the spring. It has been reared from *Laria compressicornis* Schaeffer in pods of *Acuan illinoensis*. (See fig. 10.)

Lariophagus texanus Crawford. There is every evidence that this species is a true parasite of the boll weevil, although it has not been positively reared by isolation from the boll weevil. On August 17 and 27, 1907, two specimens were reared from material collected at Hallettsville, Tex., August 13; on August 19 and 23 three specimens were reared from cotton squares collected at Victoria, Tex.; on August 29 three specimens were reared from squares which were collected at Eagle Lake, Tex., on August 14. The Victoria lot was peculiar in that it furnished the first records of *Cerambycobius cushmani* Crawford, *Spilochalcis* sp., and *Eurytoma* n. sp. This species is described as a parasite of (*Bruchus*) *Laria prosopis* Le Conte. It undoubtedly also attacks *L. sallæi* Sharp, which also breeds in the pods of huisache; furthermore, the species was reared from stem galls of *Leucosyrinx spinosus* containing *Anthonomus ligatus* Dietz.



FIG. 10.—*Habrocytus piercei*: Pupa. Much enlarged. (Original.)

Tetrastichus hunteri Crawford. This interesting new parasite of the boll weevil was first reared in the fall of 1908 from isolated parasitized individuals of the boll weevil collected at Natchez, Miss., by H. S. Smith. It is internal in weevil larvæ and pupæ and has even been reared from immature adults. A parasitized individual can easily be told by its brownish color and smoothening of the various segmental wrinkles. In more advanced stages of the parasite's development, the parasitized in-

dividual becomes a mere brown skin of parchment. This skin serves as puparium for the parasite. The developmental period is of considerable length in the fall. Specimens isolated in November do not mature until April or May. In 1908 it was found only at Natchez, Miss., and Monroe, La., but in 1909 it was reared at a number of places in Louisiana and also at Arlington, Tex. This species gives an excellent example of the adjustment of native parasites to the boll weevil.

ICHNEUMONOIDEA. ICHNEUMONIDÆ. PIMPLINÆ.

Pimpla sp. On January 27, 1909, a larva of this species was isolated from a weevil larva in squares collected at Nacogdoches, Tex. This became a mature female on February 23.

BRACONIDÆ. SIGALPHINÆ.

Sigalphus cureulionis Fitch. Previous to the summer of 1908 the first record of rearing this species (see fig. 11) from the boll weevil was considered doubtful, but beginning in August it was reared repeatedly in material from Ruston and Monroe, La., and Natchez, Miss. Its other hosts are *Conotrachelus affinis* Boheman in hickory nuts; *Conotrachelus elegans* Boheman in petioles of hickory at Dallas, Tex., and in galls of *Phylloxera devastatrix* on pecan (*Illicia pecan*) at Dallas and Victoria, Tex.; *Conotrachelus juglandis* Le Conte in walnuts (*Juglans nigra*); *Conotrachelus nenuphar* Herbst in fruit of plum, peach, etc.; *Tyloderma foveolatum* Say in stems of *Onagra biennis* at Washington, D. C.; *Trichobaris texana* Le Conte in stems of *Solanum rostratum*; *Trichobaris trinotata* Say in stems of potato (*Solanum tuberosum*); and *Zygobaris xanthoxyli* Pierce in seed of *Xanthoxylum clava-herculis*.

Urosigalphus anthonomi Crawford has never been reared since the original records which were made at Brownsville, Tex.

Urosigalphus schwarzi Crawford. This Guatemalan boll weevil parasite has never been reared in the United States.

Urosigalphus n. sp. At Arlington, Tex., in 1909, a single specimen was reared from an isolated cocoon.

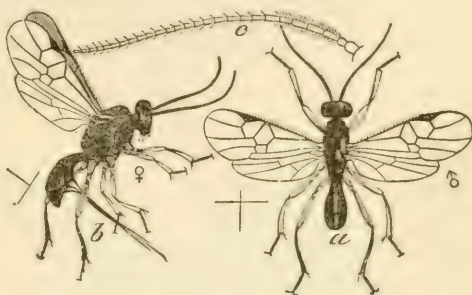


FIG. 11.—*Sigalphus cureulionis*: a, Male; b, female; c, antenna. All enlarged. (After Riley.)

BRACONINÆ.

Microbracon mellitor Say.¹ This parasite (see fig. 12) still holds the lead as the most important boll-weevil parasite. Its other host relations are only partially discovered. The following hosts have been ascertained: *Desmoris scapalis* Le Conte in heads of *Sideranthus rubiginosus*; *Smicraulax tuberculatus* Pierce in stems of *Phoradendron flavescens*; *Anthonomus albopilosus* Dietz in seed of *Croton* spp.; *Anthonomus eugenii* Cano in fruit of pepper

¹ *Bracon mellitor* Say is recorded by Girault (1907) as a parasite of the lesser peach borer (*Synanthedon pictipes* Grote and Robinson) and of the peach borer (*Sanninoides exitiosa* Say). The gregarious habit of these parasites appears to prove that the determination was incorrect. Mr. F. E. Brooks, of West Virginia, has furnished the record of this species from *Sanninoides exitiosa* and also from *Craponius inaequalis* Say at French Creek, W. Va. The determinations were made in the Bureau of Entomology. Dr. F. H. Chittenden states that he reared this species from the strawberry leaf-roller, *Ancyliis comptana* Froelich (*fragarise* Walsh and Riley), at Cabin John, Md., July 9, 1899. It is probable that all parasites of Lepidoptera determined as *Bracon mellitor* belong to some other species. The lepidopterous and coleopterous parasites are not distinguishable by structural characters, but are so different in habits that it is considered advisable to call the lepidopterous parasite *Microbracon dorsator* Say and the coleopterous parasite *M. mellitor* Say.

(*Capsicum* spp.); *Anthonomus fulvus* Le Conte in buds of *Callirrhoe involucrata*; *Anthonomus squamosus* Le Conte in heads of *Grindelia squarrosa nuda*; *Conotrachelus nenuphar* Herbst in peaches; *Tyloderma foveolatum* Say in stems of *Onagra biennis*; *Craponius inæqualis* Say in fruit of grape (*Vitis* spp.), and *Baris* sp. in roots of *Ambrosia* sp.

6. BIOLOGICAL NOTES UPON THE PARASITES OF THE WEEVIL.

A number of very interesting facts, which deserve mention in an economic bulletin, have been learned about the biology of the parasites.

ABUNDANCE OF PARASITES.

It is unusual for the parasites of the boll weevil to be found flying in numbers. Their work is in a general way quietly and unostentatiously done, but occasionally it is the privilege of the observers to see swarms of parasites hovering around the food plant of their



FIG. 12.—*Microbracon mellitor*: Adult. Much enlarged. (From Hunter and Hinds.)

favorite host. At Clarendon, Tex., in August and September, 1905, Mr. C. R. Jones and the senior author witnessed large numbers of *Microbracon nuperus* and *Tetrastichus* sp. hovering around the highly infested pods of *Mentzelia nuda*. The parasitism in pods gathered at this time was so high that much superparasitism by *Tetrastichus* upon the *Microbracon* occurred. At Ruston, La., in October, 1907, the senior author saw *Catolaccus*

hunteri flying in all directions and resting on the flowers and leaves of *Heterotheca subaxillaris* and found a very high parasitism of *Anthonomus heterothecæ* by this species. In November, 1908, in this same field at Ruston, a very high percentage of parasitism of the boll weevil by *Catolaccus* was found. In September, 1908, Mr. Hood saw many species of parasites around the flower heads of *Vernonia* at Camden, Ark. During the same month Mr. H. S. Smith found *Catolaccus hunteri* swarming on *Croton capitatus* containing *Anthonomus albopilosus*. Such observations are very important because they suggest excellent sources for parasites to be used in introduction experiments or suggest forcing of the parasites to the boll weevil by the elimination of the host.

FREQUENTATION OF NECTARIES.

The feeding habits of adult hymenopterous parasites have long escaped observation, but within recent years the intensive study of parasites has proved that very little can be accomplished in the propagation of parasites unless they can be fed. In the case of the parasites of the boll weevil it is impossible for the adults to obtain nourishment from the host in which they are ovipositing, as has been proven in the case of parasites of externally feeding insects. The host plant of the boll weevil, however, furnishes the desired food. The nectaries of cotton are about as plentiful as those of any other plant. The majority of varieties of cotton have three large nectaries on the leaves and also have them on the outside and inside of the involucre, as well as on the inside of the flower. Frequent observations of cotton plants which were producing considerable nectar have enabled us to observe practically all of the parasites of the boll weevil, as well as all of the ant enemies and many other insects. Some of these insects which visit the nectaries are injurious to the cotton plant, but the majority seem to be beneficial.

The quantity of nectar secreted by various varieties of cotton is quite variable. The variety which seems to secrete more than any other which has been observed is the Egyptian Mit Afifi. This variety is frequently surrounded by large numbers of beneficial hymenopterous insects, although at the same time it appears to be very susceptible to boll weevil attack.

HELIOTROPISM.

The majority of the hymenopterous insects which have been under observation in this investigation appear to be positively heliotropic. In general this tendency can be utilized in rearing-cage technique to induce the parasites to go into small tubes placed in the rearing boxes, from which they can be easily removed. It has been noticed in rearing cages in which there were growing plants with plenty of food, air, and heat, that the parasites sought the lightest portion of the cage rather than the plants which could give them some shade from the hot sun.

The activity of the parasites is greatest when the sunlight is most intense. Observations at the nectaries of the Egyptian cotton confirmed this. When the sun was shining the parasites were very active at the nectaries and flying around the plants, but when a cloud passed over they seemed to disappear entirely. On cloudy days none of the Hymenoptera, except the most industrious bees and wasps, was to be found at the nectar. Trelease (1879) states that "the extrafloral nectar of the cotton plant is far more abundant during night and in the early morning than at any other time, and

this is true whether we consider the involueral or foliar glands." The parasites probably frequent the nectaries during the morning sunlight hours and then are equipped to go about their other duties during the hottest part of the day.

In addition to these actual observations as to the preference of parasites there are other very strong proofs of heliotropism. It has been found that there is a decided increase in the parasitism of weevil stages in hanging forms exposed to the sun over those in fallen forms which are more or less shaded. It is also apparent that the fallen forms most exposed to the sun receive the greater amount of parasitism. Among the hymenopterous parasites there is only one at present which seems to prefer a moist shady place for its work. This is *Tetrastichus hunteri* Crawford, which is an internal parasite.

SEXES.

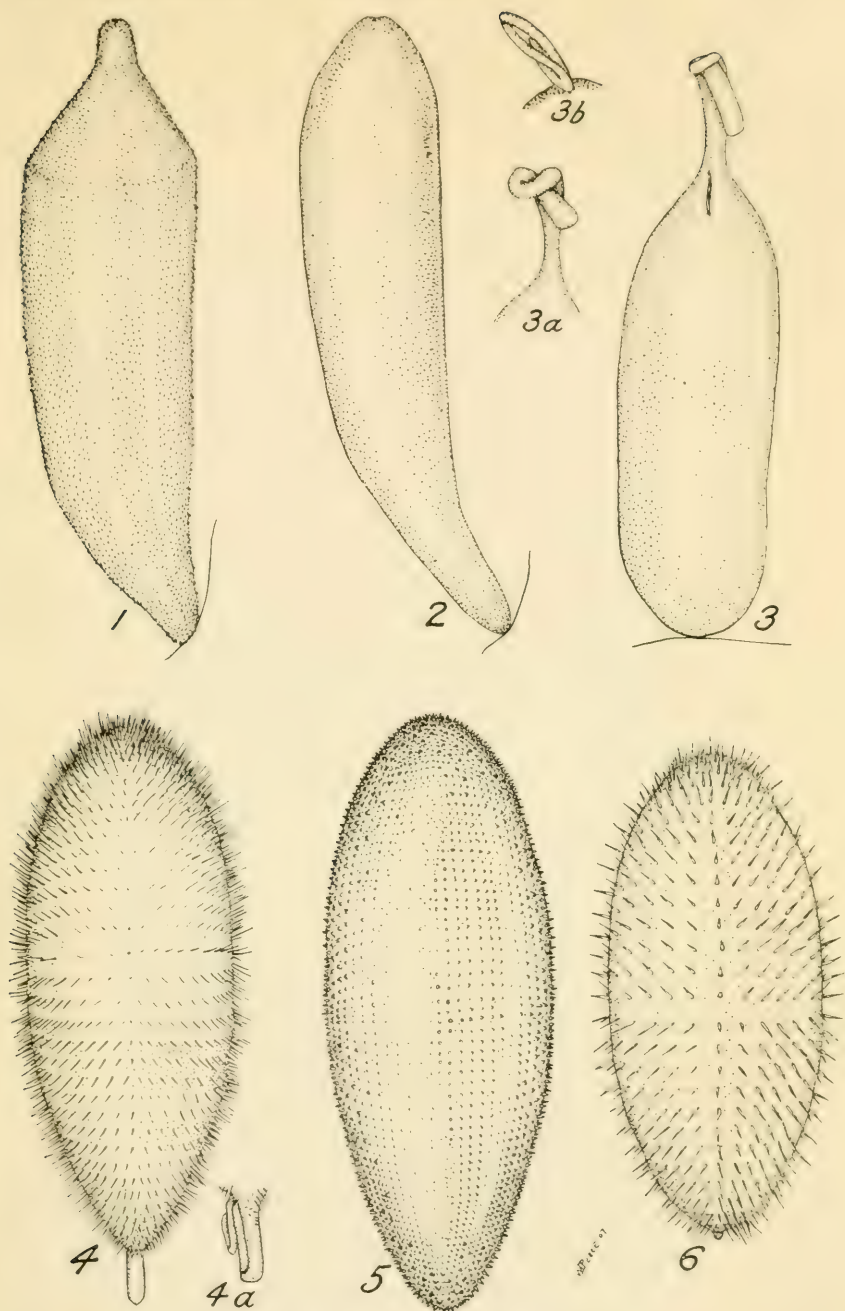
A numerical study of the records of rearing of parasites from the boll weevil shows that in the majority of the species the males are relatively fewer than the females. The following table will show the percentage of each sex and also the number of parasites upon which these percentages are based.

TABLE XIX.—Relative percentages of the sexes of boll-weevil parasites.

Species.	Total individuals.	Percentage of sexes.	
		Female.	Male.
		<i>Per cent.</i>	<i>Per cent.</i>
<i>Microbracon mellitor</i>	980	60.78	39.22
<i>Catolaccus hunteri</i>	809	78.37	21.63
<i>Catolaccus incertus</i>	429	81.12	18.88
<i>Habrocytus piercei</i>	30	100.00	.....
<i>Cerambycobius cushmani</i>	64	71.88	28.12
<i>Cerambycobius cyaniceps</i>	509	70.34	29.66
<i>Cerambycobius</i> sp.....	1	0	100.00
<i>Ennyomma globosa</i>	8	37.50	62.50
<i>Eurytoma tylodermatis</i>	433	64.90	35.10
<i>Eurytoma</i> sp.....	2	50.00	50.00
<i>Lariophagus teranus</i>	2	50.00	50.00
<i>Microdontomerus anthonomi</i>	223	84.76	15.24
<i>Myiophasia xenea</i>	2	50.00	50.00
<i>Sigalphus curculionis</i>	13	61.54	38.46
<i>Tetrastichus hunteri</i>	41	100.00	.....

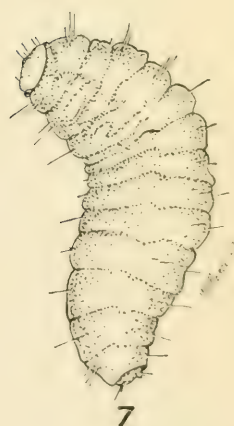
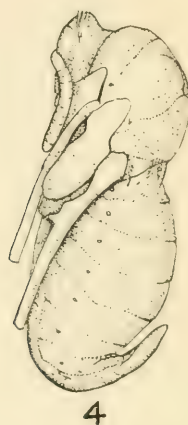
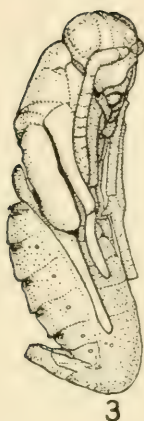
OVIPOSITION.

It has been found by numerical study of the large number of parasites collected during the last five years that whenever the parasitism in a field reaches between 50 and 70 per cent there is a strong likelihood of reduplication, with resulting superparasitism. The exact records of superparasitism obtained in this investigation have been published in another article (Pierce, 1910). Parasites have no power of discerning the presence of another egg on the prospective hosts, and hence there occurs at times a tremendous duplication of energies.



EGGS OF BOLL-WEEVIL PARASITES.

Fig. 1.—Type II. *Microdontomerus anthonomi*; Calvert, Tex., August 23, 1907; color white; size 0.38 by 0.11 mm. Fig. 2.—Type VI. Unidentified egg; Dallas, Tex., November 14, 1907, color white; size 0.85 by 0.19 mm. Fig. 3.—Type I. *Cerambycobius cyaniceps*; 3a, view from side; 3b, view from end; color white; size about 0.8 mm. Fig. 4.—Type III. *Eurytoma tylodermatis*; Dallas, Tex., August 22, 1907; color gray; size 0.68 by 0.21 mm.; 4a, side view of another egg. Fig. 5.—Type IV. *Catolaccus hunteri*; Dallas, Tex., August 22, 1907; color white; size 0.62 by 0.22 mm. Fig. 6.—Type V. Unidentified egg; Glenmora, La., August 23, 1907; color gray; size 0.44 by 0.11 mm. (Original.)



PARASITES OF WEEVILS.

Fig. 1.—*Eurytoma tylodermatis*, pupa. Fig. 2.—*Catolacus incertus*, pupa. Fig. 3.—*Cerambycobius cyaniceps*, pupa. Fig. 4.—*Microdontomerus anthonomi*, pupa. Fig. 5.—Larva of *microbracon*. Fig. 6.—*Microbracon mellilor*, pupa. Fig. 7.—Larva of chalcidoid. Much enlarged. (From Pierce.)

It may therefore be possible that a parasite will visit the same square several times and oviposit. In general it may be said that as the primary parasitism of the boll weevil increases the superparasitism also increases, with the result that sometimes the parasitism might be considerably increased if every egg reached a single host. The following instances will illustrate this. At Calvert, Tex., 41 stages were attacked by 44 parasites, although only 36.5 per cent of the weevils were parasitized. If every parasite egg had reached a host, there would have been 107.3 per cent parasitism. At Dallas, Tex., out of 309 weevil stages, 44.6 per cent were attacked by 216 parasites. The possible parasitism was 69.9 per cent. Many other instances of this kind could be given, but these two cases illustrate the condition perfectly as it exists in many places during the fall of each year.

The time for oviposition apparently differs for the various species. *Microbracon mellitor*, as a rule, oviposits before the boll-weevil larva has constructed a cell, that is, several days before the flared square falls or dries. *Eurytoma tylodermatis* appears to oviposit in squares on the plant after the normal time of falling and hence is more important in hanging dry squares. *Catolaccus* spp. and *Microdontomerus anthonomi* favor fallen forms for oviposition. The chalcids generally oviposit after the weevil larva has formed its cell. *Tetrastichus hunteri* is most frequently found in fallen squares.

7. THE DEVELOPMENT OF THE PARASITES.

THE EGGS.

The eggs of the boll-weevil parasites are all oblong-elliptic and either smooth or sculptured. The eggs of several species have at one or both ends a small tube which is tied into a knot. Six types of eggs of the boll-weevil parasites have been closely observed and designated by number in the records of rearing. These are illustrated on Plate II. The eggs of all the boll-weevil parasites are placed in the weevil cell or on the larva or pupa and usually without injuring the latter.

Type I.—Type I is the egg of *Cerambycobius cyaniceps*. It was determined for the species by the use of a mica plant cage in which the parasite was isolated with newly infested squares. This egg is about 0.8 mm. long, pure white, cylindrical, unsculptured, and with a narrow neck, which is twisted into a knot, probably by the ovipositor after the latter has released it. (Plate II, fig. 3.)

Type II.—This is the egg of *Microdontomerus anthonomi*, as shown by the rearing of an isolated specimen. The color is white, the egg being distinguished by the slightly papillose sculpture and by the nipple at one end. It measures 0.38 mm. in length and 0.11 mm. in breadth. (Plate II, fig. 1.)

Type III.—This is the egg of *Eurytoma tylodermatis*, found by the isolation of a larva seen in the act of hatching, collected at Dallas, Tex., August 22. The egg is dark-gray and thickly covered with spines. It measures 0.68 mm. in length and 0.21 mm. in breadth. The process at one end is frequently twisted. (Plate II, fig. 4.)

Type IV.—This egg was practically identified as that of a *Catolaccus* by isolation of specimens collected August 22 at Dallas, Tex. The color is white and the egg is covered with very small tubercles or papillæ. It is 0.62 mm. long and 0.22 mm. broad. (Plate II, fig. 5.)

Type V.—This egg was taken only at Glenmora, La., August 23, on two weevil stages, and has not been identified. It is dark-gray and very spiny, but the spines are larger, longer, and sparser than in Type III. The length is 0.44 mm. and the breadth 0.19 mm. (Plate II, fig. 6.)

Type VI.—This new type was discovered November 14 at Dallas, Tex., and has not yet been identified. There is no sculpturing whatever. It is pure white. The length is 0.85 mm. and the breadth 0.19 mm. (Plate II, fig. 2.)

THE LARVÆ.

The larvæ of the boll-weevil parasites live as readily on dead food as on fresh food. The hosts generally die within a very short time after the larvæ begin attack. The larvæ have been found pretty well grown with dry weevil larvæ as food. They have been found on weevil larvæ and pupæ indiscriminately and several times under the elytra of teneral or unemerged adults. Just before transforming from the larva to pupa there is considerable meconial discharge. The majority of the boll-weevil parasites are external feeders, but the larvæ of *Myiophasia ænea*, *Ennyomma globosa*, and *Tetrastichus hunteri* are internal feeders. These larvæ kill the host in a short time, its skin becoming shriveled and forming a perfect puparium for the parasite. Pupation takes place within this skin. (Pl. III, figs. 5, 7.)

Pupation.—All the chalcidoid parasites have naked pupæ. The braconids usually form silken cocoons of characteristic size, shape, mesh, or color. The cocoons of *Microbracon mellitor* are very variable in size, color, and consistency, so that they appear almost to belong to different insects. The cocoons of *Sigalphus curculionis* are generally of a rather bright yellow and with very fine silk. The pupal exuvium of the various species of chalcids and braconids is sufficiently characteristic to enable a skilled observer to determine the species after the parasite has left. (Pl. III, figs. 1-4, 6.)

Rapidity of development.—It is rather difficult to make an accurate study of the developmental period of parasites, especially when every adult parasite that matures under observation must be saved, if

possible, for further experimentation or for determination. It is inadvisable to isolate many of the parasites until the larva is partially developed, as the isolation seems to dry out both food and larva. In the study of the parasites all those in the same stage were placed on the same tray. When they passed to the next stage in development they were transferred to another tray. In this manner an accurate record was kept of the development. In order to determine the total length of the breeding period it seems best to take the total period from the collection of the material to the maturity of the last specimen and add a plus mark (+) to this figure. The total period can hardly be more than 2 or 3 days longer than the longest period thus obtained, as the egg period is very seldom more than 3 days. To obtain the exact length of the pupal period, the maximum period is taken to be the longest time from the observation of a fresh or newly-formed pupa to maturity, and the minimum time is taken to be the shortest period from the observation of the grown larva to maturity. Having thus accurately defined the pupal stage, the relative limits of the egg and larval stages are obtained by subtracting the pupal stage from the total developmental period. Table XX, which follows, presents all of the available data as they have been reduced in this manner to show the length of development of the various stages. It will be seen that most of the species pass their entire developmental period in from 20 to 30 days between June and October 15, but that after the middle of October the developing stages are caught by the cold weather and the development is suspended until spring. Thus, it is noticeable that parasites becoming larvæ in early October and November have a short larval period of probably less than 20 days, becoming pupæ before the cold wave and passing a pupal period of about 150 days. Parasite larvæ which hatch a little later are caught in the larval stage and hibernate thus for from 120 to 150 days, then becoming pupæ and maturing in from 15 to 40 days. It will be noticed that *Microbracon mellitor*, *Eurytoma tylodermatis*, and the two species of *Catolaccus* have short developmental periods during the summer, while the species of *Cerambycobius* have a little longer period. It will be noticed that *Habrocytus piercei* has only appeared in the fall of the year. This species has been recorded four years in succession and never before October. On the other hand, *Microdontomerus anthonomi* seems to be almost exclusively a summer parasite, having never been recorded after September. Of course the species of which we have records throughout the breeding season are the ones most important. This statement is borne out by the figures on the relative numbers and importance of the different species.

TABLE XX.—Lengths of developmental periods of the boll-weevil parasites.

Species and period.	June.	July.	August.	Sep- tember.	October 1-15.	October 15-30.	Novem- ber.	Decem- ber.
<i>Microbracon mellitor:</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>
Egg and larva.....	13-19	6-8	10-15	6-10	6-20	9+	-----	118+
Pupa.....	2-8	5-7	3-8	4-8	10-26	141-147	-----	14+
Total.....	21+	13+	18+	14+	30+	150+	156+	132+
<i>Habrocytus piercei:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	-----	-----	-----	20+	-----	21+	70+
Pupa.....	-----	-----	-----	-----	14+	-----	13+	15+
Total.....	-----	-----	-----	-----	34+	-----	34-138+	85+
<i>Catolaccus hunteri:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	9-14+	14-17+	9-12+	13-15	8-25+	-----	-----	70+
Pupa.....	6-11	4-7	5-7	6-8	8-22	-----	7-12	15+
Total.....	20+	21+	16-17	21+	16-33+	-----	16+	85+
<i>Catolaccus incertus:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	9-10+	9-12+	5-11+	9-12+	20-40	-----	-----	-----
Pupa.....	7-8	6-9	6-8	6-9	13	-----	-----	-----
Total.....	17+	18+	13-15	18+	33-53	-----	67+	-----
<i>Cerambycobius sp.:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	-----	-----	-----	-----	-----	-----	65+
Pupa.....	-----	-----	-----	-----	-----	-----	-----	18+
Total.....	-----	-----	-----	-----	-----	-----	-----	83+
<i>Cerambycobius cushmani:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	13+	16+	7-11+	-----	-----	-----	-----
Pupa.....	-----	3+	-12	7-11	-----	-----	-----	-----
Total.....	-----	16+	28+	18+	-----	-----	-----	-----
<i>Cerambycobius cyaniceps:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	10+	6-9	15-19	16-20	18+	-----	-----	84-113
Pupa.....	9+	10-13	7-11	8-12	7+	-----	-----	19-37
Total.....	19+	19+	26+	28+	25+	129+	139+	121-150
<i>Ennyomma globosa:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	11-16+	-----	-----	-----	-----	-----	-----
Pupa.....	-----	4-9	-----	-----	-----	-----	-----	-----
Total.....	-----	20+	-----	-----	-----	-----	-----	-----
<i>Eurytoma tyloclermatis:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	11-12+	4-10+	12-25+	8-9	11+	158+	-----	110+
Pupa.....	5-6	6-12	5-9	7-8	15-23	20+	-----	17-25
Total.....	17+	16+	21-30	16+	26+	178+	-----	135+
<i>Lariophagus texanus.</i>	-----	-----	15+	-----	-----	-----	-----	-----
<i>Microdontomerus anthonomi:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	14-15	11-36	26+	-----	-----	-----	-----
Pupa.....	-----	6-7	5-6	6-11	-----	-----	-----	-----
Total.....	20+	21+	17-41	32-37	-----	-----	-----	-----
<i>Myiophasia zenea:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	-----	8+	-----	-----	-----	-----	-----
Pupa.....	-----	-----	8-11	-----	-----	-----	-----	-----
Total.....	-----	-----	16+	-----	-----	-----	-----	-----
<i>Pimpla sp.:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	-----	-----	-----	-----	-----	-----	62+
Pupa.....	-----	-----	-----	-----	-----	-----	-----	15-
Total.....	-----	-----	-----	-----	-----	-----	-----	87+
<i>Sigalphus curculionis:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	-----	-----	-----	17-20+	-----	-----	-----
Pupa.....	-----	-----	-----	-----	13-16	-----	-----	-----
Total.....	-----	-----	-----	-----	33+	-----	-----	-----
<i>Tetrastichus hunteri:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	8-11+	-----	-----	-----	143-216+	-----	-----
Pupa.....	-----	16-19	-----	-----	-----	31+	-----	-----
Total.....	-----	27+	-----	-----	-----	174-216+	-----	-----
<i>Urosigalphus anthonomi:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	-----	-----	6+	-----	-----	-----	-----
Pupa.....	-----	-----	-----	9+	-----	-----	-----	-----
Total.....	-----	-----	-----	15+	-----	-----	-----	-----
<i>Urosigalphus sp.:</i>	-----	-----	-----	-----	-----	-----	-----	-----
Egg and larva.....	-----	12+	-----	-----	-----	-----	-----	-----
Pupa.....	-----	3+	-----	-----	-----	-----	-----	-----
Total.....	-----	15+	-----	-----	-----	-----	-----	-----

8. THE DISTRIBUTION OF THE PARASITES.

Parasites of the boll weevil have been recorded from every part of the territory so far invaded. The records are so numerous that we are able to show statistically which are the most important parasites of the weevil. The following list gives the species in their numerical rank for the entire period from January 1, 1906, to January 1, 1910, giving only the number which were accurately determined for each species. The first seven species are the most important, as has been shown in almost every section of this report. The last nine species may be considered as more or less adventitious or accidental. These species may possibly never be recorded again, or, on the other hand, they may become in the near future among the more important parasites. This very event has happened in the case of three or four of the other more important species. Up to 1906 only four of the first five in this list had been recorded from the boll weevil. The other species have been added since and some of them will become very important as the weevils enter the moister wooded regions of the East.

TABLE XXI. — Numerical rank of the parasites for the entire period, 1906 to 1910.

Species.	Number of records.	Species.	Number of records.
<i>Microbracon mellitor</i>	2,147	<i>Ennyomma globosa</i>	35
<i>Catolaccus hunteri</i>	1,094	<i>Lariophagus texanus</i>	8
<i>Catolaccus incertus</i>	578	<i>Myiophasia xenea</i>	4
<i>Eurytoma tylodermatis</i>	575	<i>Eurytoma</i> sp.....	1
<i>Cerambycobius cyaniceps</i>	574	<i>Cerambycobius</i> sp.....	1
<i>Microdontomerus anthonomi</i>	302	<i>Spilochalcis</i> sp.....	1
<i>Tetrastichus hunteri</i>	168	<i>Urosigalphus anthonomi</i>	1
<i>Cerambycobius cushmani</i>	76	<i>Urosigalphus</i> sp.....	1
<i>Sigalphus curculionis</i>	37	<i>Perilampus</i> sp.....	1
<i>Habrocytus piercei</i>	36	<i>Pimpla</i> sp.....	1

A study of the value of these parasites by years has shown that the majority of the species had not occupied the same rank in two successive years. The accompanying diagram (fig. 13), giving the yearly rank of the boll-weevil parasites from 1906 through 1909, shows that in each year new parasites were recorded and that in some cases these parasites continued to attack the weevil. *Microbracon mellitor* appears to vary but little in importance in different seasons, while *Catolaccus hunteri* shows increasing importance year by year. Some of the other parasites of considerable importance appear extremely variable in their relative rank. It will be noticed that *Habrocytus piercei* has occupied the ninth place three years in succession and is now in eighth place. This parasite occurs in small numbers, but may at any time become a leading parasite in Louisiana and Mississippi. In addition to giving the yearly rank of the species this diagram also shows the proportion of the sexes observed each year.

In order to show the regions in which the various species are of greatest importance, the accompanying map (fig. 14) is presented. This shows that while *Microbracon mellitor* has yielded more individuals than the other species, it is the predominating parasite in by far the larger proportion of the infested territory. It can also be seen that much more can be expected from the other parasites as the weevil moves eastward into their territory. *Microdontomerus anthonomi* is quite important throughout the central black-prairie region of Texas. *Eurytoma tylodermatis* is more important in north-central Texas and also in the coast region of Texas. *Cerambycobius cushmani* is charac-

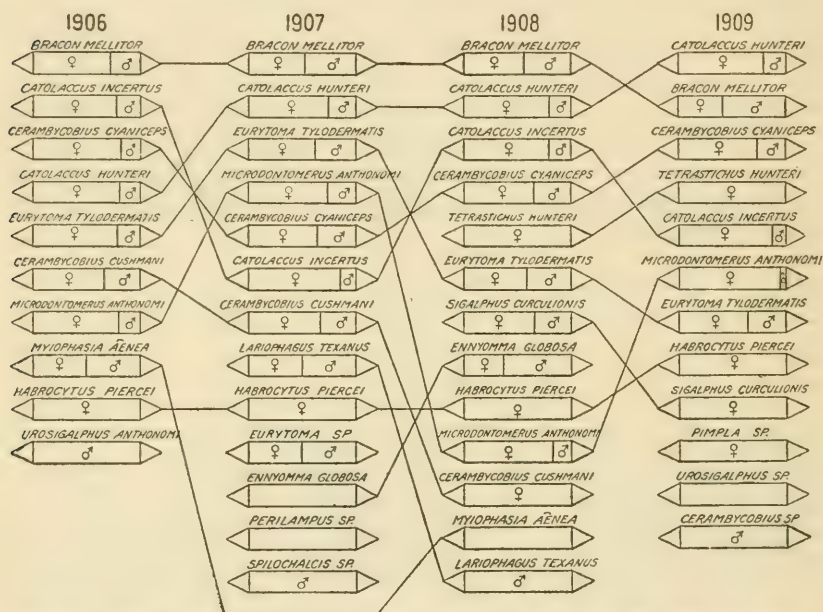


FIG. 13.—Diagram illustrating yearly rank of the boll weevil parasites, 1906, 1907, 1908, and 1909. (Original.)

teristic of the counties grouped around Victoria County, Tex., but a few specimens have been reared from the boll weevil at Alexandria, La., by Messrs. Cushman and Jones.

9. THE PARASITE SEASONS.

For the convenience of this work on parasites of the boll weevil, the year has been divided into definite parasite seasons corresponding with certain groups of conditions. The year opens with the hibernation period well underway. In so far as the parasites are concerned those which hibernate as immature insects mature generally about the middle of March. This marks the end of the hiber-

nation period or *winter* season and the opening of the *spring* season. From March until the middle of June or sometimes July there are no cotton squares for the weevils to breed in. Consequently the parasites are obliged to seek other hosts. The *summer* season is defined as beginning with the production of squares in which the weevils and their parasites may breed. Thus this season continues until squaring ceases—that is, until late in the fall when cotton is killed by frost and is succeeded by the winter season. However, we frequently distinguished a *fall* or *postmigration* season, which begins with the first



FIG. 14.—Map showing the distribution of the more important parasites of the boll weevil. (Original.)

attack of weevils upon the bolls in August and ends with the heavy frosts in October or November. The fall season is also characterized by a renewed growth of squares.

I. THE HIBERNATION OR WINTER SEASON.

The most important parasites which winter as immature stages upon the boll weevil are *Microbracon mellitor*, *Catolaccus hunteri*, *Cerambycobius cyaniceps*, *Eurytoma tylodermatis*, *Tetrastichus hunteri*, and *Habrocytus piercei*. The last two species are characteristic of winter examinations in Louisiana and Mississippi. The predatory

coleopterous larvæ *Hydnocera pubescens* LeConte and *H. pallipennis* Say are very frequently found hibernating as larvæ in the boll-weevil cells or in the cocoons of *Microbracon mellitor*. The stage in which these various parasites pass the winter is given very concisely in the table of the developmental periods (Table XX) in section 7. During January, 1910, Mr. Hood repeatedly found *Eurytoma tylo-dermatis* and *Catolaccus hunteri* hibernating in dry cotton squares and bolls and especially in hanging moss at Mansura, La.

II. THE SPRING SEASON.

It has been demonstrated that there is a definite period between the hibernation season and the first infestation of squares, extending from the middle of March to the middle of June. What happens to the parasites during this period is of considerable importance and a great amount of work has been done in the search for intermediate hosts.

In the case of *Catolaccus hunteri* the question was very satisfactorily answered. At Richmond, Tex., a large number of dewberry buds infested by *Anthonomus signatus* was gathered March 21, 1907, and this species of parasite was reared continuously between March 28 and April 1. At Victoria, Tex., Mr. J. D. Mitchell collected, on April 23, 1907, a lot of haws (*Cratægus mollis*), infested by *Tachypterellus quadrigibbus*, and on May 7 he reared this species of parasite. Investigations as to the distribution of these weevils added to the formerly known records of *Anthonomus signatus* in dewberry buds: Natchitoches and Shreveport, La.; Texarkana, Ark.; Muskogee and Ardmore, Okla.; and Trinity, Richmond, Waco, Dallas, and Marshall, Tex. *Tachypterellus quadrigibbus* was found breeding at Shreveport and Natchitoches, La., and Victoria, Tex.

At Dallas, Tex., the buds of *Galpinsia hartwegi* were found to be infested by *Auleutes tenuipes* as early as April 24. This species is a host of several species of *Catolaccus*. The buds of *Callirrhoe involu-crata* were found at Dallas to be infested by *Anthonomus fulvus* as early as April 1, and on the same date *Anthonomus æneolus* was first observed to be breeding in the buds of *Solanum torreyi*. *Solanum elæagnifolium*, with *Anthonomus æneolus* both in its buds and in the fungus leaf-galls, and *Solanum rostratum* with this weevil in the buds, appeared early in April. All of these plants continued susceptible to weevil work up to the end of the spring period, or until cotton began to square. Numerous specimens of *Catolaccus* were reared from the *Solanum*-infesting species of *Anthonomus*.

Myiophasia ænea was reared April 11, 1907, from *Conotrachelus elegans* in galls of *Phylloxera devastatrix* on the petioles of *Hicoria*

pecan, collected April 2, 1907, at Victoria, Tex., and was reared June 5, 1907, from material collected May 4 at Dallas.

Sigalphus curculionis was reared in considerable numbers between April 28 and May 7, 1907, from *Conotrachelus nenuphar* in plums gathered at Texarkana, Ark., March 26; and between April 29 and May 17, 1907, from *Conotrachelus degans* in galls of *Phylloxera devastatrix* on pecan, collected at Victoria, Tex., April 2; also between June 5 and 14, 1907, from the same species in material collected at Dallas, Tex., May 4.

Cerambycobius cyaniceps was studied very carefully at Victoria, Tex., by Mr. J. D. Mitchell during the winter of 1909-10 as an enemy of *Trichobaris texana* in stems of *Solanum rostratum*, and of *Lixus scrobicollis* in stems of *Ambrosia trifida*. Mr. T. T. Holloway conducted experiments in longevity by feeding sugared water to the parasites. Emergence began, in the lots of *Trichobaris*, on February 1 and continued until April 8. The last parasite lived until May 31. The total period of activity was 119 days and the average period lasted from March 11 to April 1. The longest record of longevity was 71 days and the average 21 days. Emergence began from the lots of *Lixus* on March 2 and continued until March 24. The last parasite lived until May 11. The total period of activity was 70 days and the average period was between March 13 and April 4. The longest record of longevity was 67 days and the average 22.

Eurytoma tylodermatis was reared from the same lots and treated in the same manner. Emergence began from the lots of *Trichobaris* on February 3 and continued until March 21. The last parasite lived until April 30. The total period of activity was 86 days and the average period was between March 10 and March 30. The longest record of longevity was 42 days, and the average 20 days. Emergence began from the lots of *Lixus* on February 22 and lasted until April 17. The last parasite lived until June 1. The total period of activity was 99 days and the average period lasted from March 16 to April 11. The longest record of longevity was 79 days and the average 26 days.

III. THE SUMMER SEASON.

The first boll-weevil parasites of the year are reared late in May or early in June in southern Texas, but in a very short time squares are forming all over the entire cotton belt and parasites may be found everywhere in small numbers as the summer progresses. The percentage of parasitism increases rapidly and generally becomes very high after August 1. Most of the important parasites may also be found on their normal summer hosts.

About the middle of August squares commence to fail, and few squares are to be found by September 1. This condition may be said to begin the fall season, when the parasites are largely obliged to seek other hosts or to attack the boll weevil in bolls.

IV. THE FALL OR DISPERSION SEASON.

Coincident with the decline in square production is the beginning of the boll-weevil dispersion which extends into new territory around the entire periphery of the infested region. In the fall there is a new growth of squares which furnishes food for the weevils before entering hibernation and also furnishes an opportunity for very high parasitism just preceding hibernation. It is during this season that parasite swarms are recorded and hence this is a very critical time for obtaining and transferring desirable parasites to new regions. During this early fall season there are several very important ways of propagating the parasites already present in the vicinity, as will be shown later. The fall season of the year closes abruptly with the first killing frost, for this crisis precipitates the hibernation period.

10. ADJUSTMENT TO NEW HOSTS.

It is a very striking fact that the continuously breeding boll weevil is attacked by parasites which in many instances attack normally weevils having but a single generation annually. Some of these parasites attack one host after another throughout the entire breeding season and may be found in activity at all periods except during hibernation. This condition is well illustrated by the accompanying diagram (fig. 15) giving the seasonal rotation of *Catolaccus hunteri* and *Cerambycobius cyaniceps*. Whether these parasites were originally single-generation species like their hosts is a question we can not now decide, but we now know that they have become adapted to many species. This fact can be most easily proven by reference to the list of hosts of the boll-weevil parasites given in the second section of this part (p. 42). It appears possible that the constantly changing factors of nature cause the various species to be continually adjusting their habits to new environments and new hosts. In other words, the groups of parasites from which the most available enemies of a new or introduced species may be obtained are those groups in which the parasitic habits are the most variable. A parasitic species that is as readily at home on a stem weevil as on a bud or seed weevil is probably able to attack many different species.

The most striking example of the adjustment of new parasites was furnished in 1907. A lot of hanging squares collected by Mr. J. D. Mitchell on August 5, 1907, at Victoria, Tex., on a field known as the Haskell field gave a percentage of 61.5. There was something so

striking about the nature of the record that Mr. Cushman was sent immediately to Victoria to study the surroundings of this field and report upon the possible reasons for the high percentage of parasitism. Mr. Cushman reported after considerable study that there were only two factors which, it seemed to him, might have an influence upon the parasites of the boll weevil. The first factor was the complete lack of fruit upon the huisache trees (*Vachellia farnesiana*) which is the normal food of *Larid sallæi*. The second factor noticed was the absence of flowers on the *Callirrhoe involucrata*, the host of *Anthonomus fulvus*. Mr. Cushman reasoned that the point would be proven if we should rear from the boll weevil some of the characteristic parasites of either this or the other species. As a result of rearings from the material collected in this field, the principal parasite was *Microbracon mellitor*, the typical boll weevil parasite, but a

SEASONAL ROTATION OF HOSTS BY *CATOLACCUS HUNTERI* CRAWFORD.

JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
		<i>ANTHONOMUS SIGNATUS</i> SAY									
			<i>ANTHONOMUS AENEOLUS</i> BOHEMAN								
			<i>TACHYPTERELLUS QUADRIGIBBUS</i> SAY								
<i>ANTHONOMUS GRANDIS</i> BOHEMAN						<i>ANTHONOMUS GRANDIS</i> BOHEMAN					
						<i>ANTHONOMUS ALBOPILUSUS</i> DIETZ					
						<i>ANTHONOMUS HETEROTHEGAE</i> PIERCE					
<i>SMICRAULAX TUBERCULATUS</i> PIERCE								<i>SMICRAULAX TUBERCULATUS</i> PIERCE			

SEASONAL ROTATION OF HOSTS BY *CERAMBYCOBIUS CYANICEPS* ASHMEAD.

		<i>TACHYPTERELLUS QUADRIGIBBUS</i> SAY									
			<i>TYCHIVUS SORDIDUS</i> LECONTE								
				<i>TRICHOBARIS COMPACTA</i> CASEY							
<i>ANTHONOMUS GRANDIS</i> BOHEMAN						<i>ANTHONOMUS GRANDIS</i> BOHEMAN					
						<i>ANTHONOMUS ALBOPILUSUS</i> DIETZ					
<i>TRICHOBARIS TEXANA</i> LECONTE						<i>TRICHOBARIS TEXANA</i> LECONTE					
<i>LIXUS SCROBICOLLIS</i> BOHEMAN								<i>LIXUS SCROBICOLLIS</i> BOHEMAN			
<i>SMICRAULAX TUBERCULATUS</i> PIERCE								<i>SMICRAULAX TUBERCULATUS</i> PIERCE			

FIG. 15.—Diagram illustrating the seasonal rotation of hosts of *Catolaccus hunteri* and *Cerambycobius cyaniceps*. (Original.)

species which is also a typical parasite of *Anthonomus fulvus*. It is probable that the latter species furnished some of the *Microbracons* for this infestation. The next most important species was *Cerambycobius cushmani*, a typical parasite of *Larid sallæi* and of *Aræcerus fasciculatus* which breeds in the fruit of the chinaberry tree (*Melia azederach*). In addition to this species, this same field yielded 3 other new parasites of the boll weevil, 2 of which are known to be parasites of the *Larid*. These were *Eurytoma* sp., *Spilochalcis* sp., and *Lariophagus texanus*.

To illustrate the divergence of habits among parasites the host relations of *Catolaccus incertus* may be cited. This parasite attacks several species of *Larid* (*Bruchus*) which are internal seed eaters and pupate in their feeding cells; such weevils as *Zygobaris xanthoxyli* and *Auleutes tenuipes*, which are seed or bud feeders and pupate in the

ground; and Anthonomines, which dwell in buds (*Anthonomus grandis*), in flowers (*A. aphanostephi*), and in hard seed (*A. albopilosus*). But it draws the line apparently at stem dwellers and is replaced by *Neocatolaccus tylodermæ* on *Lixus*, *Tyloderma*, and *Ampelogypter*. *Cerambycobius cyaniceps* is as much at home in a stem as in a bud, and so also are *Eurytoma tylodermatis* and *Microdontomerus anthonomi*. The Braconidæ appear to be more particular as to food but the most noted of all, *Microbracon mellitor*, has no preferences between stem dwellers and bud dwellers.

Thirteen miles southeast of Yazoo City, Miss., on November 1, 1909, the senior author found an isolated artificial focus of infestation by the boll weevil over 30 miles from any infestation of the same age and 20 miles beyond the regularly infested region. Out of 8 squares picked, containing 5 stages, 1 parastized stage was found.

11. BEETLES WHICH PREY UPON THE BOLL WEEVIL.

The attack of the insects predatory on the adult boll weevil is purely accidental. They may be very numerous, but the only ones recorded and verified are *Evarthrus sodalis* Le Conte and another species of the same genus. There are, however, several insects which have an actual value through their established habit of either breeding in the square upon the boll-weevil stages or of entering the square and consuming the weevil. We shall refer to four of them.

Hydnocera pallipennis Say. A single beetle of this species was reared April 6, 1907, after 183 days in its cocoon, and over 214 days isolation in the rearing tube. It was collected in a boll-weevil cell at Waco, Tex., August 28, 1906. The cocoon is very finely threaded, loosely woven, and only single layered. The stage of the beetle can easily be observed at any time.

Hydnocera pubescens Le Conte. This clerid is a very common breeder in the weevil cells. Its larvæ have been found not only feeding upon the various weevil stages but have been taken frequently from *Microbracon* cocoons which they have entered at a much younger stage.

Cathartus gemellatus Duval. This cucujid beetle is both a predator and a scavenger, its larvæ being frequently found, however, feeding upon boll-weevil stages which they must have killed.

Chauliognathus spp. The larvæ of these lampyrid beetles are very common in the squares and bolls of cotton in Louisiana and Mississippi. In one instance undoubted proof of the attack of such a larva upon one boll-weevil larva was recorded. Many other very suspicious observations were made but no definite proofs found.

12. LEPIDOPTEROUS LARVÆ WHICH ARE INCIDENTALLY PREDATORY UPON THE BOLL WEEVIL.

Alabama argillacea Hübner. The cotton leaf caterpillar is distinctly an enemy of the boll weevil and of considerable importance. When it defoliates a cotton field a month or more before the frosts it often destroys immature weevils in the cotton squares and cuts off the entire food supply of the adult weevils remaining. These weevils may be able to suspend their activities and begin hibernation but it is well known that weevils entering hibernation early in the fall can seldom survive a long hard winter, or live until cotton is up in the spring. Those that can not hibernate either die of starvation or rise in flight to seek cotton elsewhere and may perish in the effort. It is presumed that a very high percentage of flying weevils fails to find cotton.

The leaf worm is attacked by 18 predatory bugs, 16 predatory beetles, 6 predatory wasps, and the following ants: *Dorymyrmex pyramicus flavus* McCook, *Forelius maccooki* Emery, *Solenopsis geminata* Fabricius (these three ants are enemies of the boll weevil) and *Monomorium carbonarium* Smith. Ten hymenopterous parasites and one hyperparasite are known, and in addition the leaf worm is attacked by a predatory fly and by two parasitic flies.

13. ANTS WHICH PREY UPON THE BOLL WEEVIL.

HYMENOPTERA. DORYLIDÆ.

Eciton (Acamatus) commutatum Emery. This ant was taken by Mr. C. R. Jones at Beeville, Tex., attacking the boll-weevil larvæ in squares. Dr. W. M. Wheeler states that it is commonly parasitized by a round worm of the genus *Mermis*.

PONERIDÆ.

Ectatomma tuberculatum Olivier. The "kelep," or so-called Guatemalan ant, is a native of Mexico and Central America. Like all other ponerids it is slow in action. The winters have proven too severe for any of the imported colonies. The rate of development is so slow and the movements of the adults are so sluggish that little could be hoped for from this species even if it could become acclimated in this country.

MYRMICIDÆ.

Cremastogaster lineolata (Say) var. *clara* Mayr. This ant is also an enemy of the boll weevil, having been recorded attacking immature stages at Dallas, Tex., by Dr. W. E. Hinds. It has frequently been seen in the rearing cage carrying off insect prey. The species lives

in hollow stems, sticks, and galls and is commonly seen at the nectaries of cotton or attending aphides, membracids, etc. Prof. F. E. Brooks has recorded this ant as an enemy of *Heliothis obsoleta*, the cotton bollworm.

Solenopsis geminata Fabricius. The "fire ant" (fig. 16) is very common in Texas cotton fields, where it is always an enemy of the boll weevil, as well as of the cotton bollworm (*Heliothis obsoleta*) and the cotton leaf worm (*Alabama argillacea*). In Louisiana, Arkansas, and Mississippi it is very seldom seen in cotton fields, except in southern Louisiana, where unfortunately it is in danger of extermination by the Argentine ant, *Iridomyrmex humilis* Mayr. This species divides credit for the greater part of the ant control of the boll weevil with the other species of *Solenopsis*, two species of

Monomorium, and with the various species of *Pheidole*. Its nests are placed in the cotton fields, generally near the base of the plants, and from these the foragers go out in all directions in search of food. The workers have learned to detect the presence of the boll weevil in the squares and in a short time can effect an entrance into the weevil cell from which they either draw the weevil bodily or convey it in parts to their nests. This ant is sometimes found on the plant, but most commonly it does its work on the ground. The species is parasitized by (*Pseudacteon*) *Plastophora crawfordi* Coquillett at Dallas, Tex.

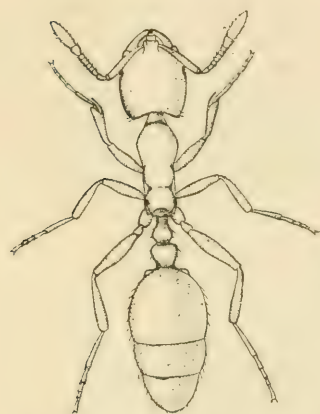


FIG. 16.—The "fire ant" (*Solenopsis geminata*), an enemy of the boll weevil: Worker. Enlarged. (From Hunter and Hinds.)

Solenopsis molesta Say (*debilis* Mayr).

This minute ant was taken in the act of attacking a boll-weevil larva by Mr. Cushman at McAlester, Okla. This species and the next are so similar in appearance that they may be easily confused. Prof. F. E. Brooks has recorded it as an enemy of *Craponius inæqualis*.

Solenopsis texana Emery. This minute ant is a common enemy of the boll weevil in Texas, Louisiana, and Mississippi. The entrance holes are very minute, but sometimes the ants enter the squares in great numbers. On October 31, 1907, at Thornton, Tex., Mr. Cushman found 85 individuals attacking a weevil larva in a single square. It is mentioned in the investigation records as attacking the weevil at Alexandria and Monroe, La., and Cuero, Lampasas, and Llano, Tex. It is also recorded as an enemy of *Heliothis obsoleta*.

Monomorium minimum Buckley. This common house ant (fig. 17) is a very valuable enemy of the boll weevil and is common in cotton

fields. It is recorded in the Dallas collection as attacking the boll weevil at Llano, Lampasas, Albany, Henrietta, Arlington, and Dallas, Tex., Ruston, La., and Roxie and Port Gibson, Miss. The species has been taken attacking the immature stages of *Trichobaris compacta*, *Anthonomus albopilosus*, and *Anthonomus fuleus*. It generally attacks these weevils as well as the boll weevil on the plant, entering the infested bud or square in search of its food.

Monomorium pharaonis L. This cosmopolitan house ant (fig. 18) is another of the most important boll-weevil enemies, being very

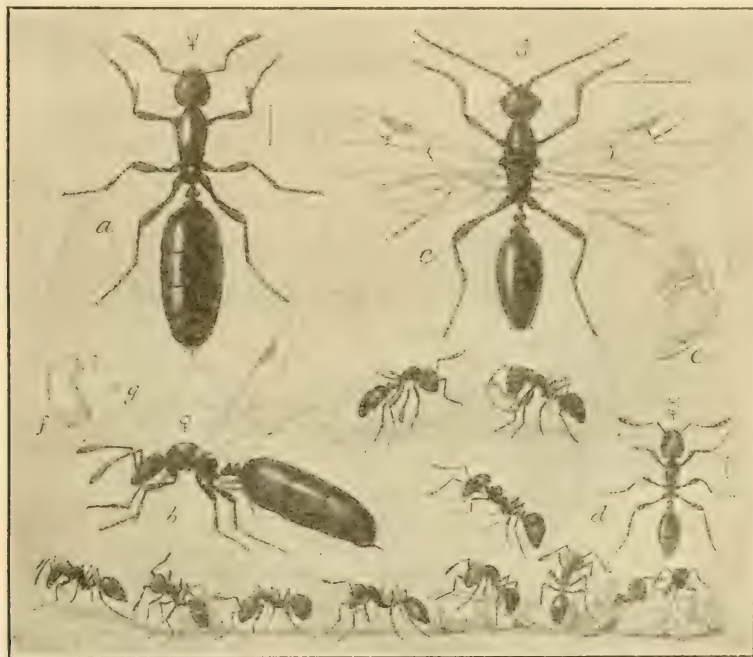


FIG. 17.—The little black ant (*Monomorium minimum*), an enemy of the boll weevil: a, Female; b, same with wings; c, male; d, workers; e, pupa; f, larva; g, egg of worker. Enlarged. (From Marlatt.)

abundant in the cotton fields of certain sections. It is represented in the Dallas collection as attacking the boll weevil at Victoria, Tex.; Fosters, Ruston, and Monroe, La., and Camden, Ark. It also attacks the weevil on the plant. In southern Louisiana it is being exterminated by the Argentine ant (*Iridomyrmex humilis*).

Pheidole sp., near *flavens*. At Arlington, Tex., August 31, 1908, Mr. Cushman found abundant evidence of the control of the boll weevil by this species. It attacks the weevil larvæ both on the plant and on the ground.

Pheidole crassicornis Emery. At Lampasas, Tex., September 23, 1908, Mr. Cushman found this ant a very abundant enemy of the boll weevil.

DOLICHODERIDÆ.

Forelius maccooki Forel. At Beeville, Tex., August 13, 1906, Mr. C. R. Jones found a high mortality of the boll weevil due to this species. Dr. Wheeler has recorded the fact that this ant prefers bare, dry ground for its nests. The species also attacks *Alabama argillacea* and *Heliothis obsoleta*. On September 7, 1908, at Dallas, Tex., Mr. F. C. Bishopp took specimens in the act of attack, and September 21, 1908, Mr. Cushman took others at Llano, Tex., attacking the weevil.

Dorymyrmex pyramicus Roger, the "lion ant," protects solitary tree cotton from the boll weevil in Cuba (Schwarz, 1905).

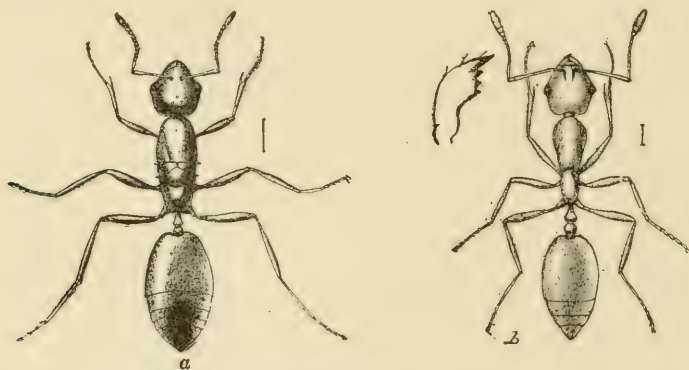


FIG. 18.—The little red ant (*Monomorium pharaonis*), an enemy of the boll weevil: a, Female; b, worker. Enlarged. (From Riley.)

Dorymyrmex pyramicus (Roger) var. *flavus* McCook. This common ant of the cotton fields has only once been taken as an enemy of the boll weevil, namely at Texarkana, Tex., by Mr. R. C. Howell, but its abundance would make it a very important species if it should develop a fondness for weevil larvæ. It is an enemy of *Alabama argillacea* and *Heliothis obsoleta*.

Iridomyrmex analis André. Specimens of this ant were found attacking the boll weevil by Dr. W. E. Hinds. This species is normally a honey ant, but occasionally takes insect food. It is very common in cotton fields, especially in Louisiana.

Iridomyrmex humilis Mayr. The much-feared Argentine ant has been taken attacking the boll weevil. It is, however, a friend to the weevil because it exterminates *Solenopsis geminata*, *Monomorium pharaonis*, and *Iridomyrmex analis* (Foster, 1908).

FORMICIDÆ.

Formica fusca (Linnaeus) *subpolita* (Mayr) *perpilosa* Wheeler. This species of ant is normally a honey feeder, but it is recorded by Rangel (Rangel, 1901c) as a predator on adult boll weevils in Mexico.

Formica pallidi-fulva Latreille. A single instance of this species cutting its way into a square infested by a boll weevil was observed by Mr. Hood at Ashdown, Ark., September 2, 1908.

Prenolepis imparis Say. A single instance of this species cutting its way into a square infested by a boll weevil was observed by Mr. Hood at Ashdown, Ark., September 2, 1908.

14. BIOLOGY OF THE COHOSTS OF THE BOLL-WEEVIL PARASITES.

The biologies of the parasites concerned in the boll-weevil complex have already been discussed. It now remains to consider the native weevils which have already or may later enter into the complex of cohosts of the boll-weevil parasites. Many of these weevils are native to the territory already occupied by the weevil, while others will become important as new territory is added. Other families of Coleoptera and even other orders of insects may later be found to be of more or less importance as cohosts of boll-weevil parasites. The late Dr. William H. Ashmead stated that *Microbracon mellitor* had been reared from many Coleoptera, while *Cerambycobius cyaniceps* bred in cerambycids and other beetles. It is important also to note the record of *Cerambycobius cyaniceps* from Languria. Our own observations have been confined to the Coleoptera of the families Lariidæ, Anthribidæ, and Curculionidæ.

PHYTOPHAGA. LARIIDÆ.

(*Bruchus*)¹ *Laria sallæi* Sharp. This bruchid is characteristic of the Gulf Coast prairie of Texas. It breeds in the pods of huisache (*Vachellia farnesiana*), is a continuous breeder, and is generally highly parasitized by *Urosigalphus bruchi*, *Cerambycobius bruchivorus*, *CERAMBYCOBIUS CYANICEPS*²; *CERAMBYCOBIUS CUSHMANI*, *LARIOPHAGUS TEXANUS*, *EURYTOMA TYLODERMATIS*, *Horismenus* sp., and several other undetermined parasites.

Laria exigua Horn. This bruchid is apparently Austroriparian and Carolinian. Its principal food plant is *Amorpha fruticosa*, in the seed

¹ The generic name *Bruchus* was first used by Geoffroy in 1762. Only one species is admissible in our code of nomenclature and this is *Cerambyx fuscus* Linnaeus, which is also the type of *Ptinus* Linnaeus 1767. The genus *Laria* was described by Scopoli in 1763 and the type thereof has been designated as *salicis* Scopoli, a synonym of *Dermestes pisorum (pisi)* Linnaeus.

Linnaeus's conception of *Bruchus* dates from 1767 and the type thereof was designated by Latreille (1810) as *Dermestes pisorum* Linnaeus. Hence we see that *Bruchus* Linnaeus (1758) is preoccupied by Geoffroy (1752) and an isogenotypic synonym of *Laria* Scopoli (1763).

Although the genus has been subdivided into several genera, our American species have not been studied with regard to such subdivision and it is hence best to consider all as in the genus *Laria*, *sensu latiore*.

² The names of boll-weevil parasites are printed in small capitals; others in italics.

pods of which it breeds prolifically. It is a continuous breeder and is highly parasitized by *Cerambycobius brevicaudus*, CERAMBYCOBIUS CYANICEPS, *Horismenus* sp., *Heterospilus prosopidis*, *Eurytoma* sp., MICRODONTOMERUS ANTHONOMI, CATOLACCUS INCERTUS, and several other species.

Laria obtecta Say. The common bean weevil is known to be parasitized by CERAMBYCOBIUS CYANICEPS and *Bruchobius laticollis*.

Laria compressicornis Schaeffer. This bruchid, which breeds in the pods of *Acuan illinoensis*, is parasitized by CERAMBYCOBIUS CYANICEPS and *Heterospilus prosopidis*.

Laria ochracea Schaeffer. This bruchid, which breeds in the pods of *Vicia* sp., is parasitized by CERAMBYCOBIUS CYANICEPS, C. CUSHMANI, *Eurytoma* sp., and *Heterospilus prosopidis*.

Spermophagus robiniae Schaeffer. This bruchid is very common in the pods of the honey locust (*Gleditsia triacanthos*), and the water locust (*Gleditsia aquatica*), both of which are trees belonging to the humid Austral zones. It is parasitized by *Heterospilus bruchi*, CERAMBYCOBIUS CYANICEPS, EURYTOMA TYLODERMATIS, and *Urosigalphus bruchi*.

RHYNCHOPHORA. ANTHRIDÆ.

Brachytarsus alternatus Say. This beetle probably breeds under many different circumstances. The only records are from a fungus gall on *Ipomœa pandurata*, and from the stems of *Elymus virginicus* and *Sideranthus rubiginosus*. It apparently belongs to the humid Austral zones. It is parasitized by MICRODONTOMERUS ANTHONOMI and a Bracon.

Aræcerus fasciculatus DeGeer. This very widely distributed Lower Austral insect (see fig. 19), known commonly as the coffee-

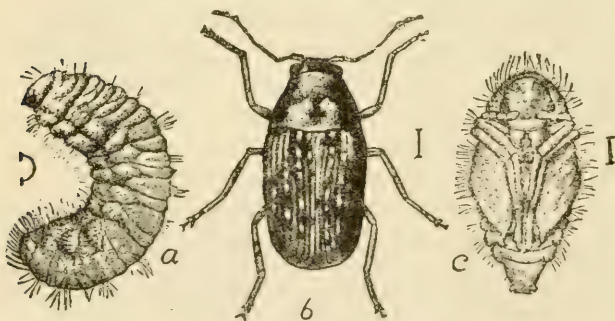


FIG. 19.—The coffee-bean weevil (*Aræcerus fasciculatus*), a cohort of boll-weevil parasites: a, Larva; b, adult; c, pupa. Enlarged. (From Chittenden.)

bean weevil, breeds in stored vegetable products, in the seed of *Theobroma cacao*, in the berry of the coffee tree (*Coffea arabica*), in diseased cotton bolls, in seed pods of *Cassia occidentalis* and *C. obtusifolia*, in seeds of *Indigofera tinctoria*, in green and decaying fruit of *Melia azedarach*, in green and dry cornstalks, and in dry acarian galls on *Ipomœa*

lacunosa. In the *Melia* berries it is parasitized by *CERAMBYCOBIUS CUSHMANI*, *EURYTOMA TYLODERMATIS*, and *PEDICULOIDES* sp.

CURCULIONIDÆ. APIONINÆ.

Apion segnipcs Say in *Cracca virginiana* is parasitized by *EURYTOMA TYLODERMATIS*.

Apion decoloratum Smith. Dr. Chittenden records this weevil as breeding in *Meibomia paniculata* and parasitized by *CATOLACCUS INCERTUS*.

Apion griseum Smith. Dr. Chittenden records this weevil as breeding in *Phaseolus retusus*, *P. wrightii*, *P. polystachyus*, and *Strophostyles pauciflora*, and parasitized by *CATOLACCUS INCERTUS*.

Apion nigrum Smith. Breeds in buds of *Robinia pseudacacia* and is parasitized by *CATOLACCUS INCERTUS*.

Apion rostrum Say in pods of *Baptisia* is parasitized by *CERAMBYCOBIUS CYANICEPS*.

CLEONINÆ.

Lixus musculus Say. This weevil is known both from the Lower Sonoran and Austroriparian zones. It breeds in the stems of *Polygonum pennsylvanicum*, *P. portoricense*, and *P. punctatum*, making an oblong gall or swelling. It is parasitized by *EURYTOMA TYLODERMATIS*, *CERAMBYCOBIUS CYANICEPS*, *Neocatolaccus tylodermæ*, *Glyptomorpha rugator*, *G. novitus*, and *Horismenus lixivorus*.

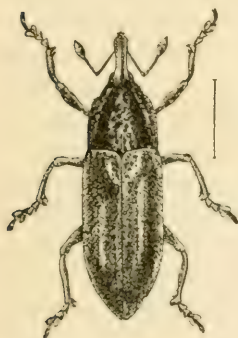


FIG. 20.—The bloodweed weevil (*Lixus scrobicollis*), a cohort of boll-weevil parasites. Enlarged. (From Hunter and Hinds.)

Lixus scrobicollis Boheman. This weevil (fig. 20) is probably confined mainly to the moist Austral zones. It breeds abundantly in the stems of *Ambrosia trifida*, *A. artemisiæfolia*, *A. psilostachya*, and *Helianthus* spp. It is quite highly parasitized by *Ptinobius magnificus*, *EURYTOMA TYLODERMATIS*, *CERAMBYCOBIUS CYANICEPS*, *Glyptomorpha rugator*, *G. mavaritus*, *G. lizi*, *Vipio belfragci*, *Microdus simillimus*, and *Horismenus lixivorus*. Mr. Townsend has

described *Lixophaga parva* from a specimen reared from this weevil at Dallas, Tex., August 15, 1907.

ERIRRHININÆ.

Smicronyx tychoides LeConte. This weevil breeds in stem galls of various species of *Cuscuta*. It is parasitized by *MICROBRACON MEL-LITOR* and *Eutrichosoma albipes*.

Desmoris scapalis LeConte. This weevil (fig. 21) occurs mainly on the black prairie in Texas and breeds in the heads of *Sideranthus rubiginosus*. It is parasitized by MICROBRACON MELLITOR.

ANTHONOMINE.

Macrorhoptus sphæralciæ Pierce. This weevil was found breeding in stems of *Sphæralcea angustifolia*. It is the host of EURYTOMA TYLODERMATIS.

Tachypterellus quadrigibbus Say. This fruit weevil breeds in the seed of apple, pear, *Cratægus oxyacantha*, and *Cratægus mollis*. It is known to us to be parasitized by CERAMBYCOBIUS CYANICEPS and CATOLACCUS HUNTERI.

Smicraulax tuberculatus Pierce. This species breeds in the stems of mistletoe (*Phoradendron flavescens*) throughout Texas, and evidence of its work has been observed in Louisiana and Mississippi. It is parasitized by EURYTOMA TYLODERMATIS, CERAMBYCOBIUS CYANICEPS, CATOLACCUS HUNTERI, and MICROBRACON MELLITOR.

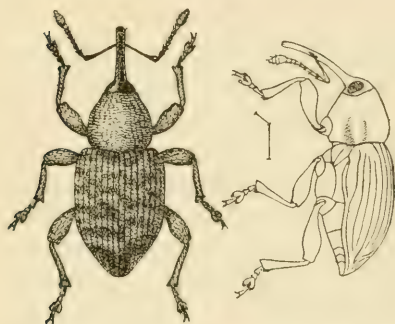


FIG. 21.—The ironweed weevil (*Desmoris scapalis*), a cohort of boll-weevil parasites. Enlarged. (From Hunter and Hinds.)

Anthonomus fulvus LeConte. This weevil breeds in the larger buds of *Callirrhoe involucrata* and *C. digitata*. It is a characteristic woodland and meadow insect in Oklahoma and Texas. The known parasites are CATOLACCUS INCERTUS and MICROBRACON MELLITOR.

Anthonomus signatus Say. The

strawberry weevil is mainly char-

acteristic of the humid Austral zones, and it breeds in the buds of strawberry, blackberry, dewberry, raspberry, *Rubus villosus*, *Potentilla canadensis*, and *Cercis canadensis*. It is parasitized by *Microbracon anthonomi*, *Calyptus tibiator*, CATOLACCUS HUNTERI, C. INCERTUS, and *C. anthonomi*. The two latter species were described from this weevil.

Anthonomus albopilosus Dietz. This little Texas weevil breeds in the capsules of *Croton capitatus*, *C. engelmanni*, and *C. texense*. It is known to us to be parasitized by MICROBRACON MELLITOR, CATOLACCUS HUNTERI, C. INCERTUS, and CERAMBYCOBIUS CYANICEPS.

Anthonomus nigrinus Boheman. This species is eastern in habitat and breeds in the buds of *Solanum carolinense*, and the potato (*S. tuberosum*). It is the host of *Entedon lithocolletidis*, *Eriglyptus robustus*, CATOLACCUS INCERTUS, and *C. anthonomi*.

Anthonomus æncolus Dietz. This Texas weevil breeds commonly in fungus galls on the leaves and in the buds of *Solanum cleagnifolium* and *S. torreyi* and also in the buds of *S. rostratum*. It is parasitized by *CATOLACCUS HUNTERI* and a *Eurytoma*.

Anthonomus eugenii Cano (*æncotinctus* Champion). The pepper weevil (fig. 22) breeds in most of the cultivated and wild peppers and may be considered a serious pest. It is parasitized by *CATOLACCUS HUNTERI*, *MICROBRACON MELLITOR*, and *PEDICULOIDES VENTRICOSUS*.

Anthonomus squamosus LeConte. This is a weevil typical of the gypsum prairie of the Lower Sonoran Zone, although occurring less abundantly in the western edge of the moist Austral zones. It breeds in the flower heads of *Grindelia squarrosa nuda*, *G. inuloides*, and perhaps also on other *Grindelias* and *Helianthi*. It is known to us to be parasitized by *MICROBRACON MELLITOR*, *CATOLACCUS HUNTERI*, and *EURYTOMA TYLODERMATIS*.

Anthonomus nebulosus LeConte. This weevil breeds in the buds of *Cratægus* in Louisiana and Arkansas. It is parasitized by *CATOLACCUS HUNTERI* and *Sigalphus* sp.

Anthonomus heterothecæ Pierce. This small weevil breeds in the flower heads of *Heterotheca subaxillaris* and probably other asteroid flowers. It is parasitized by *CATOLACCUS HUNTERI* and *EURYTOMA TYLODERMATIS*. Previous records by the senior author on *Anthonomus disjunctus* LeConte all refer to this weevil.

Anthonomus aphanostephi Pierce. This weevil breeds in the heads of *Aphanostephus skirrobasis*, and is parasitized by *CATOLACCUS INCERTUS*.

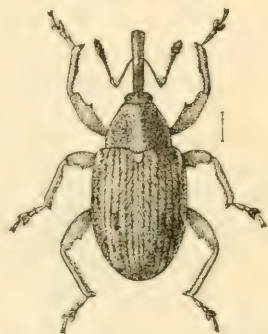


FIG. 22.—The pepper weevil (*Anthonomus eugenii*), a cohort of boll-weevil parasites. Enlarged. (From Hunter and Hinds.)

TYCHINIÆ.

Tychius sordidus LeConte. This Austroriparian weevil breeds in the pods of *Baptisia bracteata* and *B. leucantha*. It is parasitized by *CERAMBYCOBIUS CYANICEPS*.

CRYPTORHYNCHINÆ.

Chalcodermus æncus Boheman, the common cowpea weevil (fig. 23), is abundantly parasitized by *ENNYOMMA GLOBOSA*, and is likewise a host of *Ennyomma elistoides* and *SIGALPHUS CURCULIONIS*.

Conotrachelus affinis Boheman. This weevil breeds in hickory nuts and is parasitized by *MYIOPHASIA ÆNEA* and *SIGALPHUS CURCULIONIS*.

Conotrachelus juglandis LeConte. This is the walnut weevil, which is also parasitized by *MYIOPHASIA* *ÆNEA*, *Cholomyia inæquipes*, *Metadexia basalis*, and *SIGALPHUS CURCULIONIS*.

Conotrachelus elegans Say. This weevil breeds abundantly in the petioles of hickory, the galls of *Phylloxera devastatrix* on pecan, in pecan nuts, in leaf rolls on hickory, and finally in the roots of *Amaranthus retroflexus*. It is frequently parasitized by *MYIOPHASIA* *ÆNEA* and *SIGALPHUS CURCULIONIS*, and occasionally by *Cholomyia inæquipes*.



FIG. 23.—The cowpea weevil (*Chalcodermus æneus*), a cohort of boll-weevil parasites. Enlarged. (From Chittenden.)

the common plum curculio (fig. 24) breeds in the pulp of drupes and pomes. The larvæ are parasitized by *Cholomyia inæquipes*, *SIGALPHUS CURCULIONIS*, *MICROBRACON MELLITOR*, and *Porizon conotrachelii*, and the eggs by *Anaphes conotrachelii*.

Conotrachelus naso LeConte. The common acorn weevil is parasitized by *SIGALPHUS CURCULIONIS*.

Tyloderma foveolatum Say. This common weevil breeds prolifically in the stems of *Onagrabienis* and *Epilobium*. It is highly parasitized by *Neocatolaccus tylodermæ*, *CERAMBYCOBIUS CYANICEPS*, *EURYTOMA TYLODERMATIS*, *MICROBRACON MELLITOR*, *SIGALPHUS CURCULIONIS*, and *Urosigalphus* sp. nov.

Gerstæckeria nobilis LeConte (*Acalles*). The common prickly-pear weevil is parasitized by *CATOLACCUS HUNTERI* and by several other species.

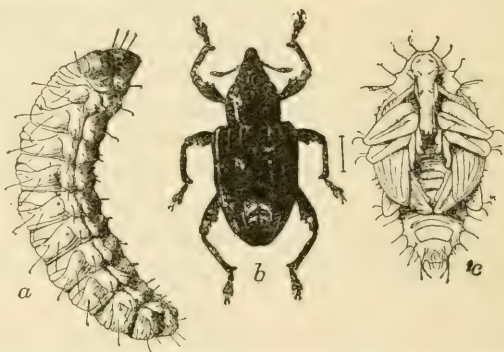


FIG. 24.—The plum curculio (*Conotrachelus nenuphar*), a cohort of boll-weevil parasites: a, Larva; b, adult; c, pupa. Much enlarged. (From Chittenden.)

CEUTORHYNCHINÆ.

Aulcutes tenuipes LeConte. This weevil breeds in the anthers of buds of *Galpinsia hartwegi* on the Texas black prairie at least. It is attacked by *CATOLACCUS INCERTUS*, *Microbracon* sp., *Eutrichosoma albipes*, and possibly by *Catolaccus nigroænea*.

Craponius inæqualis Say. This weevil breeds in the fruit of the grape. It is parasitized by *MICROBRACON MELLITOR* and *Stiboscopus brooksi*.

Rhinoneus pyrrhopus Boheman. This weevil breeds in the stems of *Polygonum* and is parasitized by *CERAMBYCOBIUS CYANICEPS*.

Ceutorhynchus n. sp. This weevil breeds in the crown of *Selenia aurea* and is parasitized by *CATOLACCUS INCERTUS*.

BARINÆ.

Baris cuneipennis Casey. This weevil breeds in the roots of *Helenium tenuifolium* and is parasitized by *CATOLACCUS INCERTUS*.

Orthoris crotchii LeConte. This Lower Sonoran weevil breeds in the seed pods of *Mentzelia nuda*. It is parasitized very highly by *Microbracon nuperus*, *EURYTOMA TYLODERMATIS*, and a species of *Tetrastichus*.

Trichobaris texana LeConte. This species breeds very abundantly in stems of *Solanum rostratum*, and is hence more or less a Lower Austral insect. Its parasites are *CERAMBYCOBIUS CYANICEPS*, *EURYTOMA TYLODERMATIS*, *MICROBRACON* sp., and *SIGALPHUS CURCULIONIS*.

Trichobaris trinotata Say. The potato stalk weevil (fig. 25) breeds in the stems of many Solanaceæ, including *Solanum carolinense*, *S. melongena* (egg plant), *S. rostratum*, *S. tuberosum* (potato), *Datura stramonium*, *D. tatula*, *Physalis longifolia*, *P. philadelphia*, *P. lanceolata*, *P. heterophylla*, and *P. virginiana ambigua*. It is known to be parasitized by *SIGALPHUS CURCULIONIS* and *EURYTOMA TYLODERMATIS*.

Trichobaris compacta Casey. This weevil breeds in the pods of *Datura stramonium* and is also recorded as breeding in *Datura meteloides*. It is parasitized by *CERAMBYCOBIUS CYANICEPS*, *MYIOPHASIA ÆNEA*, and *PEDICULOIDES VENTRICOSUS*.



FIG. 25.—The potato-stalk weevil (*Trichobaris trinotata*), a cohort of boll-weevil parasites: a, Beetle; b, larva from side; c, pupa; d, section of potato stalk opened to show larva and pupa in situ. a, b, c, Five times natural size; d, natural size. (From Chittenden.)

Ampelogypter sesostris LeConte. The grapevine gall weevil is parasitized by *MYIOPHASIA* *ÆNEA*, *Neocatolaccus tylodermae*, and *Calypsus tibiator*.

Zygobaris xanthoxyli Pierce. This weevil is abundant in the berries of *Xanthoxylum clava-herculis*. It is parasitized by *CATOLACCUS* *HUNTERI* and *SIGALPHUS* *CURCULIONIS*.

BALANININÆ.

Balaninus nasicus Say. This weevil breeds in acorns. It is parasitized by *MYIOPHASIA* *ÆNEA* and possibly by *Trichacis rufipes*.

CALANDRINÆ.

Calandra oryza Linnaeus. The cosmopolitan rice and corn weevil (fig. 26) breeds in acorns of several species of oak, in galls of *Phylloxera devastatrix* on *Hicoria pecan*, in old cotton bolls, and in all kinds of standing and stored grain. It is parasitized by *Meraporus calandræ*, *M. vandinei*, *M. utilis*, *M. requisitus*, and *CATOLACCUS* *INCERTUS*. Other parasites have been reported abroad.



FIG. 26.—The rice weevil (*Calandra oryza*), a cohort of boll-weevil parasites. Enlarged. (From Chittenden.)

15. A LIST OF THE HOST PLANTS OF THE COHOST WEEVILS.

In order to show more plainly the number and variety of plants whose presence around the cotton field, if infested by their typical weevils, would influence the parasite control of the boll weevil, the following list is presented, using the classification of Britton (1901):

Plant.	Infested by—
<i>Triticum sativum</i> (wheat).....	<i>Calandra oryza</i> L.
<i>Elymus virginicus</i>	<i>Anthribus alternatus</i> Say.
<i>Zea mais</i> (corn).....	{ <i>Aræcerus fasciculatus</i> DeG.
	{ <i>Calandra oryza</i> L.
<i>Oryza sativa</i> (rice).....	<i>Calandra oryza</i> .
<i>Juglans nigra</i> (walnut).....	<i>Conotrachelus juglandis</i> Lec.
<i>Hicoria</i> sp. (hickory).....	<i>Conotrachelus affinis</i> Boh.
<i>Hicoria alba</i> (hickory).....	<i>Conotrachelus elegans</i> Say.
<i>Hicoria pecan</i> (pecan).....	<i>Conotrachelus elegans</i> .
<i>Quercus</i> spp.	{ <i>Balaninus</i> spp.
	{ <i>Conotrachelus naso</i> Lec.
	{ <i>Calandra oryza</i> L.
<i>Phoradendron flavescens</i>	<i>Smicraulax tuberculatus</i> Pierce.
<i>Polygonum pennsylvanicum</i>	<i>Lixus musculus</i> Say.
<i>Polygonum portoricense</i>	<i>Lixus musculus</i> .
<i>Polygonum punctatum</i>	{ <i>Lixus musculus</i> .
	{ <i>Rhinoncus pyrrhopus</i> Boh.
<i>Amaranthus retroflexus</i>	<i>Conotrachelus elegans</i> Say.

Plant.	Infested by—
<i>Sclenia aurca</i>	<i>Ceutorhynchus</i> sp.
<i>Rubus villosus</i> (blackberry).....	<i>Anthonomus signatus</i> Say.
<i>Rubus trivialis</i> (dewberry).....	<i>Anthonomus signatus</i> .
<i>Rubus occidentalis</i> (raspberry).....	<i>Anthonomus signatus</i> .
<i>Fragaria virginiana</i> (strawberry).....	<i>Anthonomus signatus</i> .
<i>Potentilla canadensis</i>	<i>Anthonomus signatus</i> .
<i>Pyrus communis</i> (pear).....	<i>Tachypterellus quadrigibbus</i> Say.
<i>Malus malus</i> (apple).....	<i>Tachypterellus quadrigibbus</i> .
<i>Crataegus mollis</i> (haw).....	{ <i>Tachypterellus quadrigibbus</i> .
<i>Crataegus oxyacantha</i>	{ <i>Anthonomus nebulosus</i> Lec.
<i>Prunus</i> (plum).....	<i>Tachypterellus quadrigibbus</i> Say.
<i>Amygdalis persica</i> (peach).....	<i>Conotrachelus nenuphar</i> Hbst.
<i>Amygdalis persica</i> (nectarine).....	<i>Conotrachelus nenuphar</i> .
<i>Amygdalis armeniaca</i> (apricot).....	<i>Conotrachelus nenuphar</i> .
<i>Vachellia farnesiana</i> (huisache).....	(<i>Bruchus</i>) <i>Larix salicis</i> Sharp.
<i>Acuan illinoensis</i>	<i>Larix bisignata</i> Horn.
<i>Strombocarpus</i> (screw-bean).....	<i>Larix prosopis</i> Lec.
<i>Prosopis glandulosa</i> (mesquite).....	<i>Larix prosopis</i> .
<i>Cercis canadensis</i> (redbud).....	<i>Anthonomus signatus</i> Say.
<i>Cassia obtusifolia</i>	<i>Aræcerus fasciculatus</i> DeG.
<i>Cassia occidentalis</i>	<i>Aræcerus fasciculatus</i> .
<i>Gleditsia aquatica</i> (water locust).....	<i>Spermophagus robinia</i> Schön.
<i>Gleditsia triacanthos</i> (locust).....	<i>Spermophagus robinia</i> .
<i>Vigna unguiculata</i> (cowpea).....	<i>Chalcodermus æneus</i> Boh.
<i>Baptisia bracteata</i>	<i>Tychius sordidus</i> Lec.
<i>Baptisia leucantha</i>	<i>Tychius sordidus</i> .
<i>Baptisia tinctoria</i>	<i>Apion rostrum</i> Say.
<i>Amorpha fruticosa</i>	<i>Larix exigua</i> Horn.
<i>Indigofera tinctoria</i>	<i>Aræcerus fasciculatus</i> DeG.
<i>Cracca virginiana</i>	<i>Apion segnipex</i> Say.
<i>Robinia pseudacacia</i>	<i>Apion nigrum</i> Sm.
<i>Vicia</i> sp.	<i>Larix ochracea</i> Schaeff.
<i>Meibomia paniculata</i>	<i>Apion decoloratum</i> Sm.
<i>Phaseolus polystachyus</i>	<i>Apion griseum</i> Sm.
<i>Phaseolus retusus</i>	<i>Apion griseum</i> .
<i>Phaseolus wrightii</i>	<i>Apion griseum</i> .
<i>Phaseolus vulgaris</i> (bean).....	<i>Chalcodermus æneus</i> Boh.
<i>Phaseolus vulgaris</i>	<i>Larix oblecta</i> Say.
<i>Strophostylus pauciflora</i>	<i>Apion griseum</i> Sm.
<i>Xanthoxylum clava-herculis</i>	<i>Zygobaris xanthoxyli</i> Pierce.
<i>Melia azedarach</i> (China tree).....	<i>Aræcerus fasciculatus</i> Dietz.
<i>Croton capitatus</i>	<i>Anthonomus albopilosus</i> Dietz.
<i>Croton engelmanni</i>	<i>Anthonomus albopilosus</i> .
<i>Croton teneuse</i>	<i>Anthonomus albopilosus</i> .
<i>Vitis</i> spp. (grape).....	{ <i>Ampelogypter sesostris</i> Lec.
<i>Callirrhoe digitata</i>	{ <i>Craponius inæqualis</i> Say.
<i>Callirrhoe involucrata</i>	<i>Anthonomus fulvus</i> Lec.
<i>Sphæralcea angustifolia</i>	<i>Anthonomus fulvus</i> .
<i>Gossypium hirsutum</i> (cotton).....	<i>Macrorhoptus sphæralceæ</i> Pierce.
<i>Mentzelia nuda</i>	{ <i>Anthonomus grandis</i> Boh.
<i>Opuntia</i> (prickly pear).....	<i>Aræcerus fasciculatus</i> DeG.
<i>Opuntia engelmanni</i>	<i>Chalcodermus æneus</i> Boh.
<i>Epilobium</i> sp.....	<i>Calandra oryza</i> L.
<i>Gaura</i> sp.....	<i>Orthoris crotchii</i> Lec.
<i>Onagra biennis</i>	<i>Gerstæckeria nobilis</i> Lec.
	<i>Gerstæckeria nobilis</i> .
	<i>Tyloderma forcolatum</i> Say.
	<i>Languria</i> sp.
	<i>Tyloderma forcolatum</i> Say.

Plant.	Infested by—
<i>Galpinsia hartwegi</i>	<i>Auleutes tenuipes</i> Lec.
<i>Ipomœa lacunosa</i>	<i>Aræcerus fasciculatus</i> DeG.
<i>Ipomœa pandurata</i>	<i>Brachytarsus alternatus</i> Say.
<i>Physalis heterophylla</i>	<i>Trichobaris trinitata</i> Say.
<i>Physalis lanceolata</i>	<i>Trichobaris trinitata</i> .
<i>Physalis longifolia</i>	<i>Trichobaris trinitata</i> .
<i>Physalis philadelphica</i>	<i>Trichobaris trinitata</i> .
<i>Physalis virginiana ambigua</i>	<i>Trichobaris trinitata</i> .
<i>Solanum carolinense</i>	{ <i>Trichobaris trinitata</i> .
<i>Solanum eleagnifolium</i>	{ <i>Anthonomus nigrinus</i> Boh.
<i>Solanum heterodoxum</i>	{ <i>Anthonomus æneolus</i> Dietz.
<i>Solanum melongena</i> (egg plant).....	<i>Trichobaris texana</i> Lec.
<i>Solanum rostratum</i>	<i>Trichobaris trinitata</i> Say.
<i>Solanum rostratum</i>	<i>Trichobaris texana</i> Lec.
<i>Solanum torreyi</i>	{ <i>Anthonomus æneolus</i> .
	{ <i>Trichobaris texana</i> Lec.
<i>Solanum tuberosum</i> (potato).....	{ <i>Anthonomus nigrinus</i> Boh.
<i>Capsicum annuum</i> (pepper).....	{ <i>Trichobaris trinitata</i> Say.
<i>Datura stramonium</i>	{ <i>Anthonomus eugenii</i> Cano.
<i>Datura tatula</i>	{ <i>Trichobaris trinitata</i> Say.
<i>Ambrosia artemisiæfolia</i>	{ <i>Trichobaris compacta</i> Casey.
<i>Ambrosia psilostachya</i>	<i>Trichobaris trinitata</i> Say.
<i>Ambrosia trifida</i>	<i>Lixus scrobicollis</i> Boh.
<i>Grindelia inuloides</i>	<i>Lixus scrobicollis</i> .
<i>Grindelia squarrosa nuda</i>	<i>Lixus scrobicollis</i> .
<i>Heterotheca subaxillaris</i>	<i>Anthonomus squamosus</i> Lec.
<i>Aster salicifolius</i>	<i>Anthonomus squamosus</i> .
<i>Sideranthus rubiginosus</i>	<i>Anthonomus heterothecæ</i> Pierce.
<i>Sideranthus rubiginosus</i>	<i>Anthonomus aphanostephi</i> Pierce.
<i>Aphanostephus skirrobasis</i>	<i>Desmoris scapalis</i> Lec.
<i>Helianthus</i> spp. (sunflower).....	<i>Brachytarsus alternatus</i> Say.
<i>Helenium tenuifolium</i>	<i>Anthonomus aphanostephi</i> Pierce.
	<i>Lixus scrobicollis</i> Boh.
	<i>Baris cuneipennis</i> Casey.

16. A SUMMARY OF THE MORE IMPORTANT BIOLOGICAL FACTS.

1. The boll weevil has 54 enemies, including parasites and predators.
2. These enemies are native to other insects which are to be found in the vicinity of cotton fields.
3. The interrelationships of the boll weevil and its parasites with surrounding insects are very complicated.
4. The parasites are sometimes found in great numbers.
5. The cotton plant, by its production of nectar, furnishes a very powerful attraction for parasites and predatory insects.
6. The development of the boll-weevil parasites is as rapid as that of the boll weevil.
7. Most of the parasite species are well distributed.
8. The parasite species attack other hosts in the spring and have a generation before the boll weevil is ready for them.
9. New species of parasites are becoming adapted to the weevil each year.

10. Other cotton insects, by their ravages upon the food of the weevil, sometimes reduce the numbers of the boll weevil itself.

11. Much valuable work is done by the ants, which are present in many fields.

PART III. THE ECONOMIC APPLICATION.

The economic application of parasitic control to the boll-weevil problem is dependent upon accurate knowledge of a multitude of conditions. The preceding two parts of this bulletin have been devoted to a statement of the many phases of the parasite situation. It must be understood at the beginning of this part that we consider the utilization of parasites and other insects inimical to the boll weevil as intimately connected with good agriculture. The boll-weevil problem, from a parasite standpoint, is entirely different from any other parasite problem ever studied. In other cases such means as introductions from foreign countries may be utilized. In the present case the main problem is to devise such agricultural practices as will increase the effectiveness of the parasites already present.

In order to facilitate the treatment of the economic methods to be suggested, this part is also divided into sections, which are as follows:

1. The economic principles involved.
2. Interpretation of parasite statistics.
3. Interpretation of the biological complex.
4. How to profit by existing conditions.
5. How to plan for the greatest possible control.
6. Propagation and artificial introductions.
7. Objectionable practices.
8. The economic significance of the investigation.

1. THE ECONOMIC PRINCIPLES INVOLVED.

The attempt at utilization of insect enemies in economic entomology is now receiving so much attention that the authors will set down the principles which appear to have been the foundation of the work they have done.

1. Insects in a state of nature are more or less completely held in check by natural agencies, in which other insects frequently figure as of direct or indirect importance. Many insects are controlled almost entirely by their insect enemies. No insect is without its natural checks.

2. The relationships between an insect and its enemies can not be expressed by a simple ratio, nor are they in any way invariable. The agencies operating for and against the welfare of a given species are so many and of such inconstant magnitude, due to the activities

of other agencies, that the effects of one or two agencies of control with known strength can not be estimated, because of the many other agencies either unknown or of unknown strength.

3. When an injurious insect escapes from its natural surroundings to a region where conditions are favorable for enormous reproduction, it may become a pest, but it is never absolutely free of natural checks. *Anthonomus grandis* has never been free of its checks although it escaped those of its native home. These agencies of insect control are inherent to all countries. An insect parasite is as likely to escape its original surroundings as a phytophagous insect.

4. When an insect finds in its vicinity a variety of food closely related to its native host, and that food is more succulent or more abundant, there is a possibility that sooner or later the more inviting food will become the normal food. This possibility becomes stronger when the original food supply fails, if the species is to be continued. Not only phytophagous but entomophagous insects have frequently been proven to have thus changed their food habits—whether from preference or necessity it is not known. *Leptinotarsa decemlineata* (the Colorado potato beetle) is an excellent example of this change of habit among phytophagous insects. All of the boll-weevil parasites are examples of parasites which have adjusted their habits in the presence of their original hosts.

5. A crisis in the history of a species occurs whenever the food supply fails. The species may either disperse in search of food, as the boll weevil does each autumn, or it may hibernate or aestivate, or it may select a new host, or the species may perish. All these results occur in nature. All of these alternatives may be chosen by different individuals of the same species. It is safe to assume that when a species is found to have many hosts that it has undergone many crises and that the resultant species is a highly developed and adaptable form. A species most limited in food habit is most liable to restriction or extinction and consequently of a lower type than one able to meet any emergency.

6. When a desirable parasite species is known to be adaptable to various hosts, a crisis may be artificially superinduced by the timely elimination of the favorite hosts, thus forcing the species to attack the most predominant near-by related host in the vicinity, or it may be taken to an entirely remote or foreign locality and placed near a field containing many insects closely related to its original host, which it may learn to thrive upon.

7. The species most available for utilization are those most adaptable to changing environments, or those having the most hosts in the given locality. These other hosts will serve as nurseries for parasites.

8. Certain parasites with more or less established habits require that their hosts be in certain habitual locations (for example, *Neocatolaccus* requires stem-dwelling hosts), and in like manner there are conditions which can be made more favorable for parasite attack through cultivation or through plant selection. Furthermore, since parasites require different conditions, it is desirable to alter the existing conditions so as to make them favorable for as many species as possible. In the case of insects extending their range over many different climates it should be the aim to introduce parasites best adapted to the prevalent conditions.

2. INTERPRETATION OF PARASITE STATISTICS.

From the great mass of parasite statistics given in Part I a number of important facts need to be considered.

Parasitic and predatory attack is strongest from August until frost time. Hence it may be presumed that whatever artificial propagation is to be done will be most profitable when conducted during this period, provided it does not interfere with early fall destruction of stalks, the fundamental cultural remedy against the boll weevil.

The greatest control of the boll weevil by insects and also by all agencies is in hanging squares. As has been stated in Part I (sec. 3), the hanging squares are a result of a diagonal absciss layer, which causes the drying square to fail in separating itself completely from the plant. These squares die on the plant and afford a very favorable position for parasitic attacks upon the weevils within. The statistics show that insect control in fallen squares is greatest in the moist States of Louisiana and Mississippi. This is undoubtedly due to some of the new parasites which are accustomed to attacking woodland weevils and other insects characteristic of this humid region. The insect control in hanging squares is the greatest in the comparatively dry States of Texas and Oklahoma. These dry States also have a higher combined natural control in the fallen squares than in the hanging squares, largely because the climatic conditions cause a higher mortality of weevil stages in squares lying on the heated surface of the ground. On the contrary, the humid States have a higher mortality from both climatic and insect agencies in hanging squares than in fallen. Furthermore, it has been proven, in Part I (sec. 4), that an increase in the amount of hanging squares will increase the total control. Having these facts in mind, the obvious conclusion is that it will be desirable to have varieties of cotton which have this tendency best developed. Among the varieties which are now known to retain their squares are the cluster varieties, including the Rublee.

The figures show that parasitism becomes very high under favorable conditions and also that agriculture modifies the insect control. Obviously therefore those agricultural methods which will favor the highest insect control must be sought. These methods, as now known, will be dealt with more fully in a following section.

It was feared for a long time that the parasites of the weevil would be held in control by the warm climatic conditions which affect the boll weevil. This is not so. We have found abundant proofs of the fact that a temperature which will kill the boll-weevil larva will not kill the egg or small parasite larva in the same cell, and that the parasites can develop to maturity on the dried remains of the weevil. The temperature fatal to the boll weevil is 123° F., a temperature frequently reached on a hot burning soil. We have found in several years that a low temperature which will kill the boll-weevil larva is also not fatal to the parasites, for in November, 1907, when 97 per cent of all the boll-weevil stages were frozen, no evidence whatever could be found of mortality among the parasites. The minimum fatal temperature of the boll weevil is 12° F.

3. INTERPRETATION OF THE BIOLOGICAL COMPLEX.

The complicated biological factors which have been noted in Part II have been summarized briefly in section 16 of that part (p. 82). The interpretation of these facts has been suggested in a number of places throughout the second part. Hence only a few words are necessary at this point.

The fact that surrounding each cotton field there are numerous plants harboring weevils and their parasites is of extreme importance in this problem. These parasites are generally capable of attacking the boll weevil under conditions of necessity or alternative choice. The aim is therefore to find all the methods by which these parasites may be forced to leave their native hosts and attack the boll weevil. In fact, the entire second part has been devoted to giving these facts in order to bring out this single point.

4. HOW TO PROFIT BY EXISTING CONDITIONS.

COLLECTION OF COTTON SQUARES IN SCREENED CAGES.

As has just been pointed out, there are conditions around the cotton fields which are potential of a considerable increase in the parasitic control of the boll weevil. Probably no other method will yield better results than the gathering of the cotton squares which are infested and placing them in wire-screen cages of 16 or 18 mesh to the inch and placing these cages in selected parts of the cotton fields. This method is not new in entomological practice. It has

been used with great value in the freeing of apple orchards in Europe from the apple-bud weevil (*Anthonomus pomorum*). The boll weevils can not pass through a 16-mesh or 18-mesh wire screen, while the parasites can do so, and therefore the release of these enemies will be constantly increasing the proportion of parasites against the weevils. Even if a 14-mesh wire screen is used, only a small proportion of the weevils can escape through it and some gain is effected by the release of the parasites. In order to demonstrate numerically just how this would happen, three hypotheses are presented. In the first case squares are collected and put in a 16-mesh wire cage, and in the second case squares are collected and put in a 14-mesh wire cage, and in the third case no squares are collected. The average percentage of control which follows as a result easily demonstrates the advantage which will be almost immediately gained.

It has been contended and proven that many weevils escape through the ordinary wire screen.

I.—Given 10,000 developing stages in a 1-acre field.

(A) Collect squares containing 50 per cent of the stages and place in 16-mesh screened cage.....	5,000
Normal parasitism is 5 per cent.....	250
Ants and heat kill 40 per cent.....	2,000
Mortality.....	2,250
Breed.....	2,750
There escape through 16-mesh screen—	
10 per cent weevils.....	275
90 per cent parasites.....	225
(B) There remain in the field squares containing 50 per cent.....	5,000
Normal mortality as above, 45 per cent.....	2,250
Breed.....	2,750
Some weevils escaped from cages.....	275
Total weevils at end of generation.....	3,025
Parasites reared.....	250
Parasites escaped from cages.....	225
Parasites present in field.....	475
There is 1 parasite to every 6.3 weevils.	

II.—Given conditions as above, squares in 14-mesh screened cage.

(A) From collected squares breed.....	2,750
There escape through 14-mesh screen—	
40 per cent weevils.....	1,100
All parasites.....	250
(B) Breed in field.....	2,750
Escaped from cages.....	1,100
Total weevils at end of generation.....	3,850

Parasites reared.....	250
Parasites escaped.....	250
Parasites in field.....	500
There is 1 parasite to every 7.7 weevils.	

III.—Given 10,000 developing stages in a 1-acre field.

No squares are collected.....	10,000
Normal parasitism, 5 per cent.....	500
Ants and heat kill 40 per cent.....	4,000
Mortality.....	4,500
Breed.....	5,500
Parasites reared, 500.	
There is 1 parasite to every 11 weevils.	

SUMMARY.

	Squares not collected.	Squares collected and placed in—	
		14-mesh wire cage.	16-mesh wire cage.
Weevils remain.....	5,500	3,850	3,025
Parasites remain.....	500	500	475
Ratio of parasites to weevils.....	1: 11	1: 7.7	1: 6.3

ELIMINATION OF COHOSTS.

Another practice of undoubted value in bringing about a higher percentage of parasitism upon the boll weevil is the elimination of the cohosts of the boll-weevil parasites at proper times. To show what has been done in this line, the case of the Dallas farm in 1907 may be cited. On July 19 of that year a very large hedge of weeds, *Ambrosia trifida*, infested by *Lixus scrobicollis* was cut. These weeds were along the fence adjoining a part of the cotton field which had been under close observation for parasites throughout 1906 and the spring of 1907. In 1906 there was not found in any plat on this farm a higher parasitism than 2 per cent by *Eurytoma tylodermatis* in hanging squares. *Eurytoma* was very numerous in the *Ambrosia* weeds next to this field, but did not appear to attack the weevil in large numbers. Before the weeds were cut in 1907 the two plats nearest these weeds averaged 26.76 per cent and 16.79 per cent parasitism by *Eurytoma*. On August 17, about a month after these weeds were cut, the two plats just mentioned had, respectively, 37.50 per cent and 26.66 per cent parasitism by *Eurytoma*. This striking gain adjoining the weeds was not reflected by parts of the field farther removed.

EARLY DESTRUCTION OF THE COTTON STALKS.

There can be little doubt that the early destruction of the cotton stalks, in addition to depriving the boll weevil of its food plant, will also cause the parasites to seek a series of hosts which can carry them through the winter period. In order to prove that fall destruction does not have an injurious effect upon parasite control, we would cite the discussion of the Victoria fields, in which various methods of fall destruction were carried out, as discussed in Part I, section 6. As a further proof the famous Olivia fall-destruction experiments may be considered.

On October 1 to 10, 1906, all of the cotton plants in over 400 acres, constituting the entire Olivia cotton community in Calhoun County, Tex., were cut and burned under the direction of Mr. J. D. Mitchell. According to the rearing records in our possession, the parasites developing in this cotton would all be mature before November 10, and if they hibernated, would have to do so as adults. No other cotton existed within 12 miles, as the community is completely isolated by water and marshland.

Cotton was planted about March 15, 1907. On April 15 no boll-weevil work could be found, but on May 7 a single weevil was found after a careful examination of eight fields. On the same date at Six Mile settlement, across the bay near Port Lavaca, there was considerable infestation. If the parasites hibernated as adults they would be dead long before the middle of June. If they could have hibernated as immature stages they would have matured by March 15, and under normal conditions three generations would have passed by June 15. The infestation was still very slight in July. It must be argued, therefore, that any boll-weevil parasites must be breeding on some other weevil, if they did not perish.

On August 22, 1907, Mr. Mitchell found parasites with weevil-infested squares on a field in the opposite part of the community to that in which he first found the weevil infestation. The obvious inference is that a rotation of hosts occurred during the period of the boll weevil's absence.

Having planned the cropping system, it is also best to prepare the fields early for cotton and plant as early as possible. Of course, most of the reasons for early planting of cotton are well known and the practice is very common, but in this connection it must be said that such early planting has the actual advantage of enabling the parasites to start early.

Care must be given to the choice of the cotton variety which is to be used. Frequent recommendations have been made of varieties with light foliage, early maturing fruit, short nodes, and determinate growth. All of these qualities are favorable to parasite control,

especially since such plants afford much more sunlight on the ground. The ants and also the parasites prefer much more to attack the squares which are dried out than moist squares. It seems that they can more readily penetrate the linings of the square. In addition to these qualities of the cotton variety, the use of a variety with at least a moderate amount of nectar is also advised. The reason for this has been explained in preceding paragraphs. Finally, the tendency of plants to retain the squares must be again mentioned. If a variety can furnish the desired qualities of early producing, productiveness, and quality of lint, as well as a diagonal absciss layer on the square, that variety should be chosen above others.

If at all possible, it is advisable to plant the rows far apart or on the check-row system, in order to give the necessary amount of sunlight. The cultivations to follow this should be with the purpose of obtaining a dust mulch, for with such a mulch the surface of the soil may be heated to a much higher degree than by deep and lumpy cultivation, and the control of the boll weevil will thus be greatly increased, through the drying effect upon fallen squares.

5. HOW TO PLAN FOR THE GREATEST POSSIBLE CONTROL.

As it has been proven that many agricultural processes are favorable to the development and attack of parasites and enemies, there can be no question but that it is desirable to plan to obtain the greatest amount of this beneficial aid.

There are a few plants which have no objectionable qualities in themselves which might with good reason be planted adjacent to the cotton fields in order to induce the attack of weevils which act as hosts of the boll-weevil parasites. For instance, the presence of a hedge of blackberries or dewberries along the fence means the presence of *Anthonomus signatus*, the blackberry bud weevil, with its numerous parasites, all of which attack the boll weevil. The parasites would be able to carry on a generation in the spring before the boll weevils were breeding and would mature in plenty of time to attack the first developing stages of the boll weevils.

It would seem advisable to plant a hedge of the flowering shrub *Amorpha fruticosa*, which is the host plant of *Larix exigua*. This little weevil is very abundantly parasitized.

In planning the cropping system there can be no possible harm in arranging to have a forage or hay crop adjacent to the cotton field. In case a forage crop is used, cowpeas with the ever-present cowpea pod weevil would undoubtedly bring about the presence of several important parasites. The early removal of the cowpeas for fodder would force the parasites to attack the boll weevil. In the case of a hay field, the process of haying and subsequent curing

would enable the parasites present in the various weeds to escape and attack the most abundant host, namely, the boll weevil.

If, with all these precautions, the boll weevils are very numerous in the field, and the expense is not too great, much can be gained by picking the squares and placing them in cages, as has been described in a previous section.

Finally, at the proper season for haying, the actual methods of cutting and preparing the hay will without doubt furnish still greater control to the weevil. Some time in September, if not before, whether haying is carried on or not, there should be a thorough cutting of all weeds around the cotton field in order to force the parasites to the boll weevil and also to get rid of favorable hibernation quarters for the boll weevil.

6. PROPAGATION AND ARTIFICIAL INTRODUCTIONS.

The propagation of parasites under artificial conditions and their introduction are attended with a great amount of labor and expense and have many technical difficulties. The simplest form of propagation is the collection of infested squares at one locality and the shipment of them to another locality, where they are placed in the field to await results. There are good reasons for attempting thus to introduce parasites. It has been found by very close observations that the parasites are not evenly distributed, but that each species has a more or less definitely defined geographical region. This is no doubt due to the distribution of the normal host weevils. The purposes of introduction are to take these parasites from their native localities and place them in geographical regions in which they do not at present exist. Definite proofs that results can be obtained in this manner were to be had at Dallas on the experimental farm in 1906 and also in 1907. The 1906 experiment has been fully described in the first report on the parasites of the boll weevil (Pierce, 1908a). In 1907 a similar experiment was tried by the release of large numbers of adult parasites. These parasites were carried to a field in small screen cages containing foliage, so that the parasites might not become overheated. The cages were opened in the shade, and the parasites allowed to fly out in any direction which they pleased. While many species of parasites were released in this manner, they did not all show the results that were expected, but the release of *Catolaccus incertus* in a given part of the field accomplished an increase in the control in hanging squares by this species. In two other parts of the field *Microbracon mellitor* was released, and it also showed good gains. As *Microbracon* was released on this farm both in 1906 and 1907, it may be useful to compare the percentages of parasitism at various periods. In August, 1906, this species furnished 8.5 per cent parasitism in hang-

ing squares; in September, 1906, this had risen to 10.2 per cent; in July, 1907, the parasitism by this species was 35.2 per cent, and in August, 1907, it had risen to 39.8 per cent.

At Shreveport, La., in 1908, many specimens of *Catolaccus incertus* and *Microbracon mellitor* were released. Table XXII gives an idea of the results and shows the expected increase by *Catolaccus* in both hanging and fallen squares and by *Microbracon* in hanging squares.

TABLE XXII.—*Experiment in artificial introduction of Catolaccus incertus and Microbracon mellitor, Shreveport, La., 1908.*

Class of forms.	Plat.	Date.	Percentage of mortality.				Gain in mortality.		
			Total.	Para-sites.	Cato-laccus.	Micro-bracon.	Total para-sites.	Cato-laccus.	Micro-bracon.
Fallen squares....	Release...	Oct. 5	36.44	5.93	4.23	1.70	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Do.....	do.....	Oct. 28	37.96	15.74	10.80	2.16	165	150	33
Do.....	Check.....	Oct. 5	40.00	10.50	5.55	3.70			
Do.....	do.....	Oct. 28	42.33	16.00	8.00	5.00	52	44	35
Hanging squares....	Release.....	Oct. 5	47.15	9.90	4.39	3.29			
Do.....	do.....	Oct. 29	64.86	37.84	10.81	18.91	282	148	477

RELEASE CAGES.

In order to obtain satisfactory results from the release of infested material, it is necessary to place the material in cages from which the injurious weevils can not escape but which will still allow the parasites egress. This principle has been explained in other sections. There is also another important consideration in the construction of the cages. When a large amount of material such as this is collected in a small space it furnishes great inducements to attack by colonies of ants. The only way that the material can be protected from total destruction by ants is the isolation of the cage on legs by the use of "inverted cups" containing oil, or by greasing the legs in some manner.

TRANSFER OF ANT COLONIES.

Since the work of ants is always very favorable to control, means should be devised of increasing their numbers in the cotton field. The dust-mulch method of cultivation is very favorable to the ants in that it does not disturb their colonies after they have commenced breeding. This is a very important matter to consider. The late Mr. F. C. Pratt, in working with the horn fly (*Lyperosia irritans* L.) discovered that fresh manure containing numerous fly larvæ is very attractive to *Solenopsis*, and that these ants seem to transfer their whole colony at times to the manure. Mr. Wilmon Newell, in connection with the Argentine ant investigations, at a later date, found that he could trap immense colonies of the Argentine

ant (*Iridomyrmex humilis*) by means of boxes containing manure. These observations are very suggestive, for they point out the possibility that colonies of ants can be obtained by placing fresh manure in boxes near ant colonies. When sufficient numbers have entered, they may be boxed up for removal to a place desired. In this manner great colonies could be transferred bodily for considerable distances.

7. OBJECTIONABLE PRACTICES.

There are several practices which are quite objectionable from the standpoint of encouraging the parasites and most of which have also been found objectionable from purely cultural standpoints. When the cotton is planted closely on moist soil its growth is mainly vegetative and consequently immense stalks may have very little fruit. Agriculturists have always pointed out that large cotton plants need plenty of room in order to produce fruit. Field examinations to determine the mortality of the boll weevil from various causes have always shown that the parasitism is greatest in the portions of a field where the foliage is lightest. A notable example was found at Natchez, Miss., where in a single field the growth was very irregular. One spot seems to have been used for feeding cattle and was very fertile. On this spot the cotton grew 6 or 8 feet tall and the ground was densely shaded. Here the mortality of the weevil was very low, and there was scarcely any control by insects. One hundred feet from this was a thin piece of ground where the cotton plants were barely 2 feet high, but they were loaded with bolls and showed a much higher percentage of mortality, especially by insect enemies. An actual count of the number of bolls in the two parts of the field was greatly in favor of the smaller plants.

Late planting has been proven objectionable from almost every standpoint from which it has been viewed. Under existing circumstances there are no valid arguments for late planting. From the standpoint of control by parasites late planting simply delays the attack of parasitic enemies and reduces the amount of control in the fall at a critical time.

It is believed that the use of varieties which always tend to drop their squares is objectionable if varieties with the opposite tendency can be found with the same qualities of production.

The practice of picking squares and then burning them can not be condemned too strongly. The planters are by this practice almost nullifying the good work that they do by picking the squares. They are doing nothing more or less than destroying their best friends when they burn these squares. This may be proven by an hypothesis similar to those presented (p. 87) in demonstrating the value of collecting the infested squares.

Given 10,000 developing stages of the boll weevil in a 1-acre field.

(A) Collect and burn squares containing 50 per cent of the stages..... 5,000

This destroys *all parasites* as well as weevils.

(B) There remain in the field squares containing 50 per cent of the stages
present..... 5,000

Normal parasitism 5 per cent..... 250

Ants and heat kill 40 per cent..... 2,000

Mortality..... 2,250

Weevils to breed..... 2,750

Parasites present in field, 250.

There is 1 parasite to every 11 weevils.

This method undoubtedly greatly reduces the total number of weevils in the field, but, as can be readily seen, the proportion of parasites to weevils is the same as if nothing had been done—namely, 1 to 11. It was shown that by placing the squares in 16-mesh wire cages the proportion would be 1 to 6.3. Hence it appears that by the caging method the planter leaves in his field a more active agency than he had before to attack the many weevil stages he has undoubtedly missed, whereas by the burning method he has not in the least improved his field conditions.

8. THE ECONOMIC SIGNIFICANCE OF THE INVESTIGATION.

In final summary the following points are emphasized:

I. *The control of the boll weevil by insect enemies is sufficiently great to give it a high rank in the struggle against the pest. A considerable portion of the insect control would not be accomplished by any other factor; hence it is by no means to be neglected.*

The number of species of insects attacking the developing stages is 49.

The control in any given place consists of the combined work of several different species.

Places having the largest number of controlling insects have the highest percentage of control.

In many places insect control is considerably greater than climatic control or than any other class of factors.

The average insect control is 20 per cent of all immature stages or two-fifths of the entire natural control.

The cotton leaf-worm is a valuable enemy of the boll weevil when it defoliates the cotton after September 1, a date beyond which new squares can not be expected to mature. It kills many weevils by starvation, kills many others while consuming the squares, and finally forces a premature hibernation which is generally fatal.

II. *The amount of control due to the various factors at work in any given place should be increased if possible. Parasites can be introduced into new fields.*

In order to prevent serious injury to cotton, the mortality of the weevil should be above 90 per cent. It has averaged over 57 per cent for four years and has reached almost 100 per cent several times.

While climatic influences occasionally bring the control above 90 per cent, they can not be regulated or in any way directly utilized.

Although the insect enemies present at a given place may be accomplishing the greatest amount of work possible, the fact remains that if other species of enemies are introduced and become established the control can be increased.

Since certain parasites attack the weevil preferably in dry locations and others in wet locations, and since some prefer to attack the infested forms on the plant, while others seek them on the ground, it is possible to select the insect agencies so as to obtain the least amount of lost or duplicated energy.

III. *The parasites and predators which attack the boll weevil are native insects, already present in a given territory before the weevil arrives.*

The predators, especially ants, will attack almost any kind of insect food. The parasites in nearly all cases are capable of attacking almost any kind of weevil breeding in herbs above ground or in fruits.

The parasites have proven their ability to adjust themselves to the boll weevil by attacking it in its first generation in newly infested territory in instances where the actual sources of the parasites were demonstrable.

The weeds surrounding the cotton fields contain many weevils which are harboring multitudes of available parasites. These parasites may be induced to attack the boll weevil by the timely elimination of their native hosts.

This leads to the recommendation that planters cut the weeds adjoining the cotton fields, along the roadsides, turn rows, and fences about the time of the maturing of the crop.

It also leads to the recommendation that a field adjoining the cotton be used as a pasture or hay field, and that this field be mowed early in the fall. The usual haying will also bring about the same result—namely, the elimination of other plants harboring weevils which attract the parasites needed in the cotton patch.

It is advisable to have in the vicinity of the cotton field such plants as the dewberry, Croton, Amorpha, cowpeas, etc., which contain other hosts of the boll-weevil parasites.

IV. *The cultural methods of controlling the cotton boll weevil are the most favorable methods of cotton culture from the parasitic standpoint.*

The tendency of the principal boll-weevil parasites to prefer light and heat leads immediately to a long series of recommendations.

Heat on the ground is essential for the climatic control of the weevil and also for parasitic control. Although the two factors overlap, each accomplishes considerable independent control.

A heated condition of the ground may be accomplished by planting the rows far apart, by check-row planting, by flat cultivation, or by planting varieties which have short limbs, or shed their foliage early, or have small leaves.

Fall destruction of the cotton plants cuts off the parasites from breeding on the weevil but sends them to other hosts upon which they can breed a winter generation, or pass hibernation, thus gaining not only a generation on the weevil but providing for themselves during the winter.

The early planting of cotton in the spring makes it possible for the earliest parasites to attack the weevil.

V. The tendency to retain infested fruit, which is displayed by certain varieties, is worth consideration.

The fact that many more parasites are reared in hanging squares than in fallen squares makes it desirable in humid regions to have many of the hanging squares in a field in order to serve as a nursery of parasites for the weevils in the fallen squares.

Varieties which show an elongate diagonal connection between the square and stem will tend to have an imperfect absciss layer formed. Prominent in this class are the cluster boll varieties of cotton. *It is recommended that search be made for such a variety as will retain its infested forms and at the same time fulfill the other requirements in the making of a good crop.*

VI. Any step which will diminish the number of weevils and not diminish the number of parasites in a field will of course increase the percentage of parasites present.

The most important step of this kind is the collection of infested squares and placing them in cages with a screen through which the weevils can not escape but the parasites can.

Ant colonies may be introduced into the fields in boxes of fresh manure.

If squares are collected, they should not be burned, but should be placed in screened cages.

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L. O. HOWARD, Entomologist and Chief of Bureau.

CALOSOMA SYCOPHANTA:

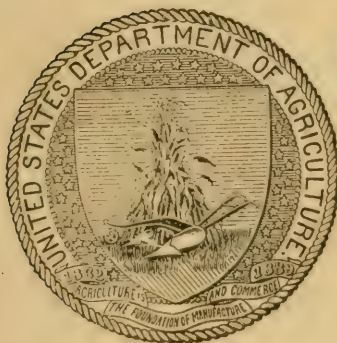
ITS LIFE HISTORY, BEHAVIOR, AND
SUCCESSFUL COLONIZATION
IN NEW ENGLAND.

BY

A. F. BURGESS,

Expert in Charge of Breeding Experiments.

ISSUED DECEMBER 8, 1911.



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CALOSOMA SYCOPHANTA.

Adult eating gipsy moth caterpillar, lower left; pupa, lower right; eggs, upper left; eaten chrysalides of gipsy moth, upper right; full-grown larvæ from above and from below. (Original.)

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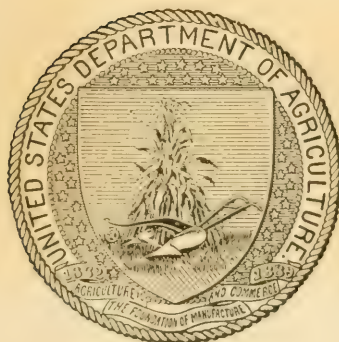
ITS LIFE HISTORY, BEHAVIOR, AND
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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., June 3, 1911.

SIR: I have the honor to present for publication a manuscript on the subject "Calosoma Sycophanta: Its Life History, Behavior, and Successful Colonization in New England," by Mr. A. F. Burgess, of this bureau. The insect in question is one of the most important of the natural enemies of the gipsy moth and the brown-tail moth which have been imported from Europe. The work on its life history and the means of establishing it has been in Mr. Burgess's charge. He is particularly skilled in this class of work, and has achieved a notable success in this investigation.

I recommend that this paper be published as Bulletin No. 101 of this bureau.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau

HON. JAMES WILSON,
Secretary of Agriculture.

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CALOSOMA SYCOPHANTA:

ITS LIFE HISTORY, BEHAVIOR, AND SUCCESSFUL COLONIZATION IN NEW ENGLAND.

INTRODUCTION.

It has long been known that certain predaceous beetles common in Europe belonging to the family Carabidae, particularly *Calosoma sycophanta* L. and *Calosoma inquisitor* L., are enemies of the gipsy moth and the brown-tail moth, as well as other lepidopterous larvæ, and as soon as the work of importing the natural enemies of the first-mentioned insects into Massachusetts was begun an effort was made to secure these species for liberation.

Calosoma sycophanta (Pl. I) is a beautiful green beetle about 1 inch in length. It is provided with long legs and is able to run and climb very rapidly. The tarsal joints of the front legs of the female are dilated and spongy beneath, while those of the male are similar to those on the other legs. (See fig. 1.)

In the spring of 1905 an arrangement was made between the State of Massachusetts and the United States Department of Agriculture whereby the introduction of the natural enemies of these moths was to be carried on cooperatively, and Dr. L. O. Howard, Chief of the Bureau of Entomology, was given general supervision of the work. In order to organize a corps of collectors, so that large quantities of material could be secured and promptly shipped to this country, he sailed for Europe early in the spring of that year and engaged competent entomologists in several countries to take charge of that branch of the service.

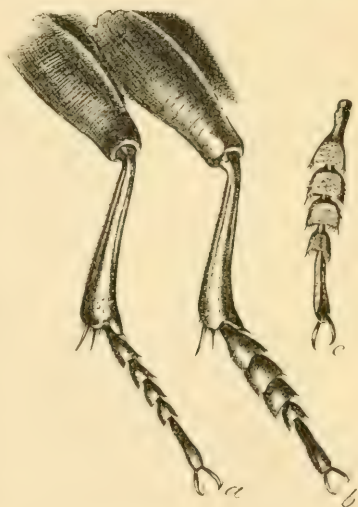


FIG. 1.—Front leg of female and of male of *Calosoma sycophanta*, showing differences in structure of front tarsal joints: a, Female; b, male; c, underside of male tarsus. (Original.)

IMPORTATIONS OF CALOSOMA BEETLES FROM EUROPE AND JAPAN.

Between July 15 and August 1, 1905, 216 specimens of *Calosoma sycophanta* were received from Dr. G. Leonardi, of Portici, Italy, which were collected in Sardinia, but only one of the beetles was alive when the shipments reached the laboratory at North Saugus, Mass. The death of so many of the insects was due to their being packed in tin boxes, which are not suited to the purpose, and also to the fact that they were sent by the way of London and New York, which caused considerable delay in their arrival.

During the year 1906 shipments were received from Miss Marie Ruhl, Zurich, Switzerland, who had in her employ a large force of collectors who sent material to her, which she packed and mailed to the Gipsy Moth Parasite Laboratory. Of 25 shipments received from her, 15 contained specimens of *C. inquisitor* and the balance *C. sycophanta*. Three shipments of the latter species were also received from Dr. Leonardi, which were collected in Italy. The material was unpacked and cared for at the laboratory by Mr. E. S. G. Titus, who had been detailed by Dr. Howard to take general charge of the material imported. He was assisted by Mr. F. H. Mosher, who was employed by the State of Massachusetts in the parasite investigations. Two hundred and eighty specimens of *C. inquisitor* and 693 of *C. sycophanta* were received in living condition during the season. Several colonies were liberated in the field and the remaining specimens were confined in large cages out of doors to secure data on their habits.

During the summer of 1907, 967 live specimens of *C. sycophanta* were received. This represented less than one-half of the number shipped. The reason for the high mortality will be explained later in this paper. The first lots were cared for by Mr. Mosher, who liberated several colonies. Early in the summer Mr. Titus resigned to accept another appointment, and Mr. W. F. Fiske was placed in charge of the parasite work.

On July 21, 1907, an arrangement was made whereby the work on predaceous beetles was placed in charge of the writer, who was at that time conducting insecticide investigations for the State of Massachusetts. Mr. C. W. Collins, an employee of the State office, was detailed to assist in the beetle work and has since devoted most of his time to this work.

In the summer of 1908, 675 specimens of *C. sycophanta* were received from Miss Ruhl, and also numerous specimens of other species of *Calosoma* and *Carabus*, said to be beneficial in Europe. The latter were received in such limited numbers that little more could be done than to make life-history studies and an investigation of their food

habits. Some of these studies have shown very interesting results, which it is hoped may be published later.

Four hundred and five specimens of *C. sycophanta* were received in 1909, and in addition 25 larvæ of this species arrived in boxes with parasitized gipsy moth material. Specimens of other carabids were also sent in limited numbers.

During the summer of 1910, 1,305 living specimens of *Calosoma sycophanta* were received from Miss Ruhl and several shipments of miscellaneous species of *Carabus* came from the same source. For the first time since the work was begun specimens of *Calosoma* and allied genera were received from Japan. A very few individuals reached the laboratory in healthy condition, and these were used for rearing work.

The following table gives the number of live specimens of *C. sycophanta* received since the work began.

TABLE I.—*Number of live specimens of Calosoma sycophanta received in Massachusetts, 1905 to 1910.*

Year.	Number received.	Year.	Number received.
1905.....	1	1909.....	405
1906.....	693	1910.....	1,305
1907.....	967		
1908.....	675	Total.....	4,046

Sixty-seven per cent of these beetles were liberated in field colonies and the balance was used for experimental and reproduction work.

METHODS OF PACKING PREDACEOUS BEETLES FOR SHIPMENT.

Considerable difficulty is always experienced in shipping living insects long distances, especially if it is necessary to collect and forward them when they are active, and also if they must reach their destination in season to feed and reproduce without serious interruption. Species that can be packed when dormant can be easily transferred from one place to another, but it has not been found possible to do this with predaceous beetles.

In 1905, as has already been stated, the beetles imported were packed in tin boxes, and practically all of them died in transit. Two kinds of boxes were used for the purpose. One style (fig. 2) consisted of a tin box $6\frac{1}{2}$ inches wide, $10\frac{1}{2}$ inches long, and $2\frac{1}{2}$ inches deep. It was divided in the center by a partition, and small partitions were soldered to it, so as to make 20 compartments. In each of these a beetle was placed, as well as a gipsy-moth caterpillar or pupa. The box was wrapped with stout paper and shipped by mail. On arrival it was found that the beetles had attacked the food placed in the compart-

ments, and, as the tin did not absorb the moisture, the beetles became covered with the decomposed remains and death resulted.

The other method of using a tin package was to place several beetles with larvæ for food and a small quantity of sphagnum moss in each box. The results, however, were not satisfactory.

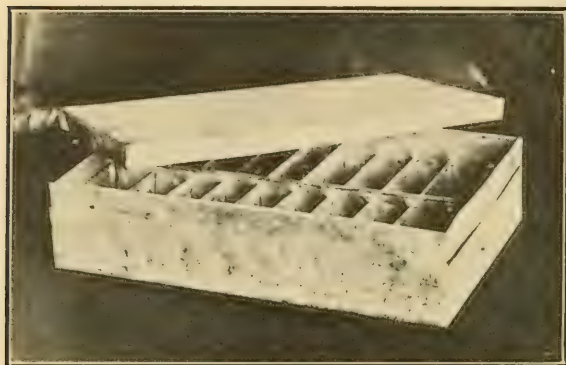


FIG. 2.—One of the tin boxes used for making the first shipments of *Calosoma* beetles. (Original.)

bles were received in less than 48 hours from the time they were collected.

In 1906 the European material was shipped in wooden boxes instead of tin. These boxes (fig. 3) were made of $\frac{1}{4}$ -inch stock, the usual size being $7\frac{1}{4}$ by 4 by $2\frac{1}{4}$ inches. Inside of these were packed match boxes, such as are used for safety matches, each of which contained a small quantity of sphagnum moss and a single beetle. (See fig. 4.) Occasionally two beetles were placed in a match box, but better results were secured when only one was inclosed. By using this method of packing and placing wet moss in the boxes the mortality during shipment for the year 1906 was 15 per cent in the case of *Calosoma sycophanta* and 38 per cent in that of *Calosoma inquisitor*. In 1907 no specimens of *C. inquisitor* were received, and 54 per cent of *C. sycophanta* died in transit. This was principally due to the moss being very dry in the boxes

In the spring of 1909 several lots of the native beetle *Calosoma scrutator* were shipped to the laboratory from Washington, D. C. They were packed separately in small tin boxes with a little wet sphagnum moss and arrived in good condition. No food was put into the boxes, and the bee-

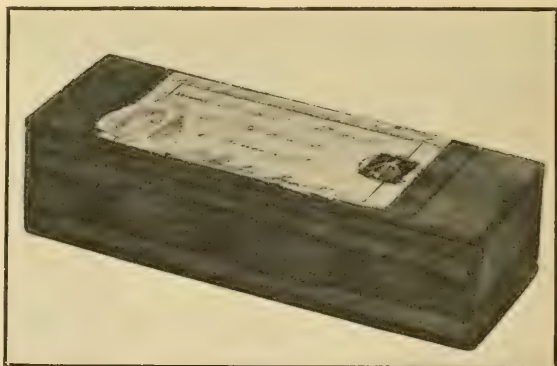


FIG. 3.—One of the wooden boxes used for shipping *Calosoma* beetles from Europe. (Original.)

and also because in many of the shipments sawdust was used instead of moss, and proved unsuitable for the purpose. At the close of that year instructions were sent that in the future wet moss should be placed in the match boxes with the beetles, and since that time the rate of mortality has been reduced. In 1908 only 14 per cent and in 1909 9 per cent of the specimens of *C. sycophanta* were dead when received.

Nearly all the material above mentioned was shipped by Miss Ruhl. In 1909, however, a small number of larvæ of *C. sycophanta* was received in boxes of parasitized gipsy moth caterpillars from M. Oberthür and M. Dillon in collections made in France. Lots sent by the former were shipped from Charroux and those by the latter from Hyères.

In 1910 all the specimens were received from Miss Ruhl, and 27



FIG. 4.—Same box as in figure 3, with cover removed to show method of packing *Calosoma* beetles. Each match box contains a single beetle and a small quantity of wet sphagnum moss. (Original.)

per cent mortality resulted. Table II shows the entire numbers of adult *C. sycophanta*, their condition on receipt, and the percentage of mortality.

TABLE II.—Number of specimens of *Calosoma sycophanta* shipped into Massachusetts, 1905 to 1910, number received alive, and percentage of mortality.

Year.	Number of beetles shipped.	Live specimens received.	Per cent of mortality.
1905.....	216	1	99.5
1906.....	821	693	15
1907.....	2,092	967	54
1908.....	788	675	14
1909.....	444	405	9
1910.....	1,782	1,305	27
Total.....	6,143	4,046	
Average.....			34

During the different years this species has been received in greater or less numbers from March to September. The bulk of the shipments usually arrives between June 15 and July 15.

Little difference can be noted in the mortality during this period. When apparent advantage is shown for any particular time of shipment, it is probably due to other causes, such as good packing, rapid transit, or to the fact that the packages were placed in favorable situations on the boats or trains. A record has been kept since 1907 of the mortality of the sexes during shipment, but from this data it appears that the difference is very slight, as practically the same percentage of males and females dies during the season. Nine per cent mortality is as low as can be expected, as some of the shipments are always delayed in delivery, and a certain number of the beetles, especially

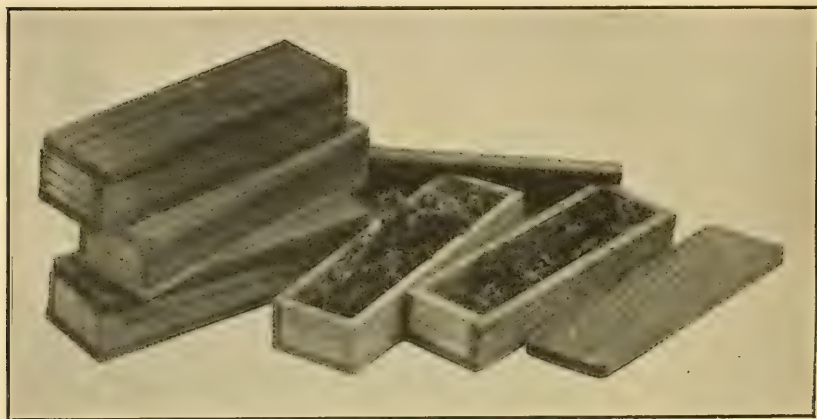


FIG. 5.—Wooden boxes from Japan, showing method of packing *Calosoma* beetles for shipment. (Original.)

when they are collected in midsummer, would die if allowed to remain in their native home.

The average length of time in transit in 1906 was 10 days, but in a few cases 12 to 14 days elapsed. These figures represent a fair average of the length of time required to ship material from France, Switzerland, or Italy. These beetles can be shipped in a satisfactory manner in cold storage, and this method has been used for Japanese shipments. They were packed separately in wooden boxes (fig. 5) with moist sphagnum moss, and 40 or 50 of these were inclosed in larger wooden boxes, which were placed in the cold room on the boat. On arrival at Vancouver they were forwarded by express and were kept iced until they reached the laboratory.

From this experience it appears that these beetles can be shipped satisfactorily by mail if they are properly packed and are not on the road more than two weeks. The moss in the boxes must be moist; otherwise the percentage of mortality will be large.

EUROPEAN DISTRIBUTION OF *CALOSOMA SYCOPHANTA* AND HOSTS ATTACKED.

An examination of the European literature gives very little data concerning the distribution of *Calosoma sycophanta*. It is reported as being present throughout France and in Germany, and a few examples have been found in England. There is a single record of this species having been taken in Ireland. Specimens have been received from Italy, and it probably occurs in other European countries.

Réaumur¹ published, in 1736, a general account of the life history of this species and a description of the larva, although he failed to rear the beetle. He states that he has seldom found a nest of the processionary caterpillars that did not contain from 1 to 6 of these larvæ feeding in the midst of their prey. This information has been quoted by many subsequent writers.

Burmeister, in a paper published in 1836,² says: "I have often had occasion to observe this insect (*Calosoma sycophanta*), which is not rare in the pine woods in the neighborhood of Berlin, in the larva, as well as in the perfect state, in both of which I have seen it employed in devouring the larvæ of [*Porthetria*] *Liparis dispar* and other moths, which are very common in the vicinity of the capital." Several other reports mention its feeding on gipsy moth caterpillars.

Westwood states that Nicolai has found this species in the forests near Halle, Germany, feeding on *Porthetria dispar* and the pine sawfly, *Lophyrus pini* L.

Valuable information concerning the larvæ of this insect and other species of *Calosoma* has been published by M. G. de La Pouge, in papers issued by the University of Rennes and in other publications.

PLAN OF WORK AT THE LABORATORY.

On taking charge of the work on predaceous beetles at the Gipsy Moth Parasite Laboratory, plans were made to conduct it along two distinct lines, viz., investigational work and field colonization. As many important facts relating to the life history, food, habits, and the possible influence that each imported species would exert in checking the increase of the gipsy moth and the brown-tail moth were unknown, it was necessary to make careful studies and investigations in the laboratory and field. This work required the utilization of a considerable number of the live insects that were imported. The main object, viz., the liberation of natural enemies in the field, has never been lost sight of, and this feature has been given considerable attention. Field notes have been made concerning the conditions in

¹ Mémoires pour servir à l'Histoire des Insectes, 1736, vol. 2, p. 455, pl. 37, figs. 14-19.

² Trans. Ent. Soc. London, vol. 1, p. 235, 1836.

the colonies where beetles were liberated each year, so that their spread and increase could be followed as accurately as possible from year to year.

September 1, 1907, the writer was appointed as expert in charge of breeding experiments in this bureau, and since that time has been engaged in the work during the summers, while the winters have been devoted to other lines of work in Washington. Mr. C. W. Collins, as already stated, has been engaged in the work almost continuously except for a part of the time each winter when other work required his attention. April 1, 1909, he was appointed an expert in this bureau.

During the summer of 1908 Mr. C. W. Stockwell assisted in the rearing work; in 1909 a considerable amount of this work was attended to by Messrs. P. H. Timberlake and S. S. Crossman; and in 1910 Messrs. K. W. Brown, J. J. Culver, and R. G. Smith were similarly engaged. Many of the valuable records that are included are the result of the careful work of these men who, with Mr. Collins, performed most of the tedious work of feeding the various species under observation and kept daily records of the experiments. Mention should also be made of the valuable notes contributed by Messrs. J. V. Schaffner, jr., and E. A. Proctor, who have been engaged in making field observations in the colonies that have been liberated.

The writer is also under obligation to Mr. W. F. Fiske for his general interest and many helpful suggestions; to Mr. F. H. Mosher and various members of the staff of the State foresters' office for suggestions and information concerning field conditions; to Mr. H. R. Gooch, who constructed most of the apparatus used; and to Messrs. H. S. Barber and W. N. Dovener for preparing the illustrations accompanying this report.

The facts brought out in the investigations that have been carried on will be given first, as these have an important bearing on the colonization work which will be described in detail later in the report.

The data which follow refer chiefly to *Calosoma sycophanta*, as this species has been imported in greatest numbers. Others have been given such study as was possible, and it is hoped that more individuals may be received, so that further investigations and liberations can be made.

INVESTIGATIONAL WORK ON CALOSOMA SYCOPHANTA.

In 1906 the investigational work was carried on by Messrs. Titus and Mosher, and some notes and observations were made by Mr. R. L. Webster. During the following summer Mr. Mosher attended to the work until it was taken up by the writer. Beetles were confined in large cages covered with cheesecloth, where they were supplied with caterpillars for food. Several styles of cages were used, and these were located in woodland near the laboratory at North

Saugus, Mass. The average size was 8 feet 6 inches by 11 feet 4 inches, with 8-foot posts. The roof was covered with canvas, and a strip of this material was attached to the sills and extended into the ground to prevent the escape of the insects. It was found that these cages were too large for the purpose of securing detailed data concerning reproduction and the exact amount of food consumed, and the following year they were used only in a limited way.

EQUIPMENT USED FOR REARING PREDACEOUS BEETLES.

Following out the methods used by the writer in 1896-97, when investigating the life history of some of our native species of this genus, an attempt was made to keep this species under observation

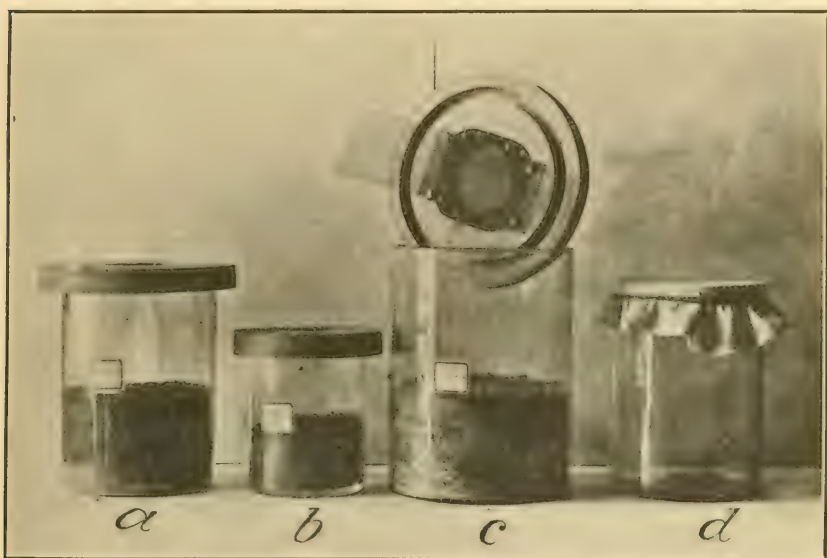


FIG. 6.—Jars for rearing *Calosoma* beetles: *a*, Large jar with wooden top and "ladder"; *b*, small jar with wooden top; *c*, showing construction of top and "ladder"; *d*, jar with cheesecloth top held in position with rubber band. (Original.)

in glass jars partly filled with earth. The best results were secured by using glass battery jars, which can be obtained from most dealers in glass supplies. The size of the jars selected should be governed by the size of the species to be studied. The best results with *syco-phanta* were secured by using jars 8½ inches tall and 6½ inches in diameter, or 7¼ inches tall and 5½ inches in diameter, all outside measurements. After the first season a wooden cover was used instead of the usual cheesecloth top. (See fig. 6.) One-inch boards, an inch larger in diameter than the top of the jars, were used for the purpose. These had a 2-inch hole bored in the center which was covered with wire netting. A groove cut near the outer edge of the cover allowed it to fit loosely on the jar. In rearing beetles it has been found of advantage to extend the wire which covers the hole in

the top so that one end of it will reach the earth in the jar. This forms a "ladder" and enables the beetles to climb to the top of the jar and secure the caterpillars which have sought shelter on the underside of the cover.

Jelly glasses partly filled with earth are useful in rearing small larvæ when it is desired to secure accurate records of the length of time in the different stages, the amount of food consumed, and similar details. When the larvæ are nearly full grown it is sometimes necessary to place them in larger jars with more earth or in a tight wire cage which has been partly buried in the earth, as it is necessary for them to have plenty of earth in which to form their pupal cham-

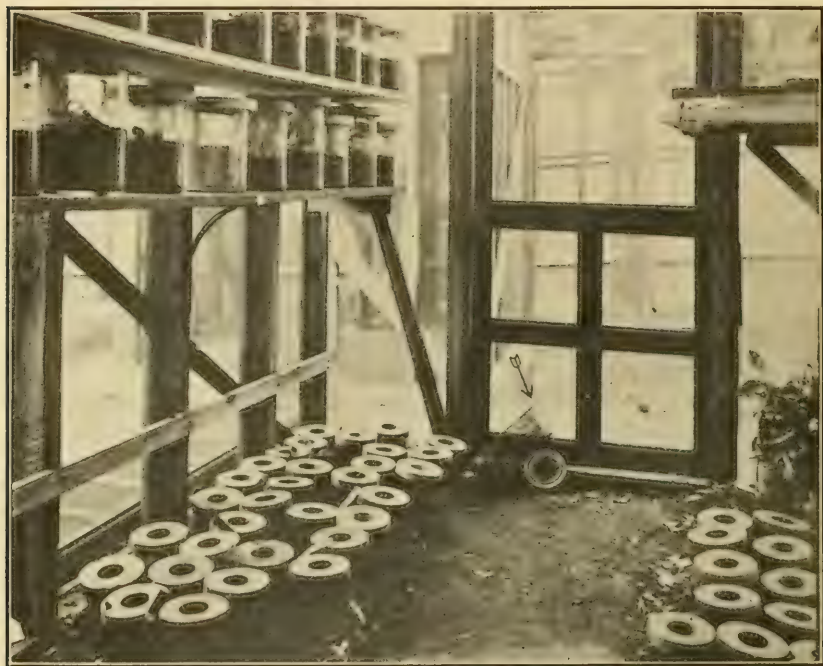


FIG. 7.—Small wire-screen cages, set in ground in insectary, for rearing *Calosoma* larvæ. The arrow points to an empty cage and cover. (Original.)

bers, and if they are to be reared successfully the ground should not be disturbed.

Cages for rearing *Calosoma* larvæ have been in use the past three seasons. The bottoms are made of a circular piece of board 4 inches in diameter, having a hole in the center covered with netting. To the circumference of this base is tacked a strip of wire mosquito netting 10 inches wide. It must be cut long enough to lap at the side so that it can be sewed with wire. The selvage of the wire netting should be used for the top of the cage, and care should be taken that the circumferences of the top and the bottom are the same. A cover similar to those used on the glass jars is then placed on the top of the cage. These cages (fig. 7) should be set about 8 inches in the ground,

and larvæ when nearly full grown can be fed in them if desired. The cages should not be disturbed until the following spring, and at that time the beetles which developed will come to the surface of the ground in the cage and can be easily removed.

It is always necessary to provide hibernating quarters for beetles late in the summer, as they pass the winter in the adult state. Boxes of any desirable shape can be used for this purpose. They should be 18 to 24 inches deep, and the bottom should be replaced with galvanized iron wire netting, $\frac{1}{4}$ -inch mesh. (See fig. 8.) They should be set in the ground and filled with earth within 4 to 6 inches of the top. A hinged cover on which the same kind of wire netting is used is a necessity, and the box should be supplied with a lock, so that its contents can not be disturbed by persons of an inquiring turn of mind.

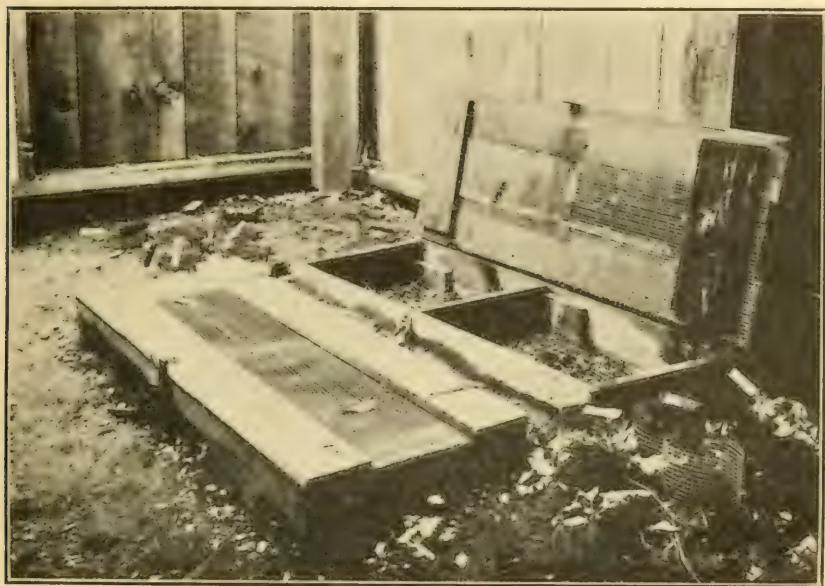


FIG. 8.—Box cages for hibernation of *Calosoma* beetles. (Original.)

We have also found it desirable to use, for hibernation cages, galvanized iron wire cylinders having a $\frac{1}{4}$ -inch mesh, which are constructed in the same manner as those used for feeding large larvæ. (See figs. 9 and 10.) They are of special value for confining specimens during the winter which have been used for rearing or other special records. Cages similar to the last two types described were used late in the summer of 1909 for feeding large numbers of the larvæ of *sycophanta*, but netting with a fine mesh had to be substituted to prevent the escape of the small larvæ.

It should be stated that the use of these cages had been adopted after several years of experimental work. Many tests of different

kinds of rearing devices have been made and a large number of disappointments has marked the gradual perfection of the methods and devices employed. In the fall of 1907 a considerable number of beetles was placed in hibernating cages made of galvanized iron bent into the form of cylinders which were sunk in the ground about 20 inches, allowing 4 inches to protrude. Each end was covered with mosquito netting and these appeared to furnish excellent quarters for wintering beetles. Experience showed that the earth in these cages became so wet and later so compact that practically all of the beetles died, some of them being crushed in their pupal chambers.

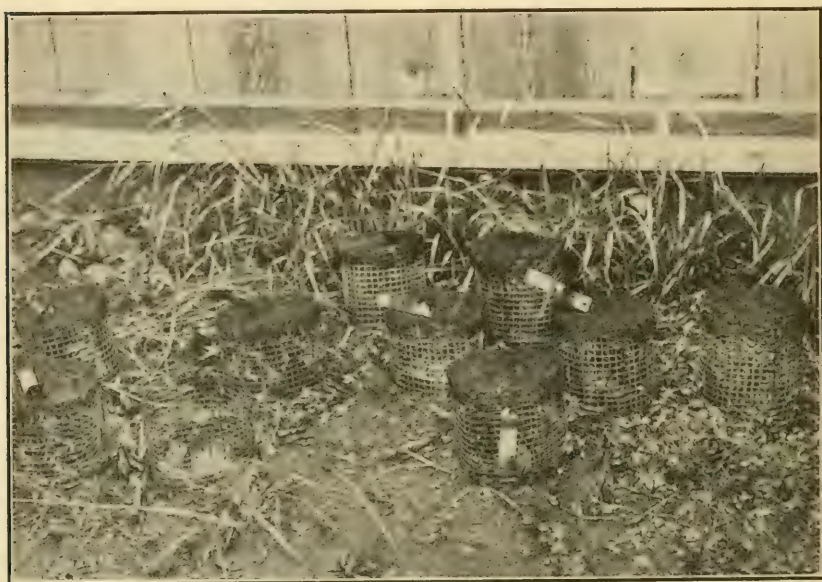


FIG. 9.—Galvanized-iron wire cages used for wintering pairs of *Calosoma* beetles. (Original.)

Fortunately all of the rearing stock of the season was not placed in such cages so that the work the following spring did not have to be discontinued on account of lack of living specimens.

OUTDOOR INSECTARY FOR REARING CALOSOMA BEETLES.

In the spring of 1908, after moving to the present laboratory at Melrose Highlands, it seemed desirable to build a temporary insectary for rearing beetles during the summer. Accordingly a house 11 feet 4 inches by 5 feet 10 inches with posts 5 feet 6 inches in height was built in the yard at the rear of the laboratory. (See fig. 11.) The lumber used was 2 by 3 studding, and the sides were walled in with mosquito wire. The rafters extended about 6 inches beyond the plates and the roof was covered with canvas which was held in place

with furring. The sills of this house rested directly on the ground and canvas curtains were provided on the south and west sides to shut off the direct sunlight during hot weather. Shelves were placed along the inside walls of the house and the earth on each side of a central walk was used for ground rearing cages.

It was found that the heat was too great in the top of the house during midsummer, and the following spring, when it was necessary to have more space for beetle rearing, another house (Pl. II, A) was built. Cement walls 4 inches wide were used for a foundation and the posts were 8 feet in height. Several partitions were built in one side of the house which provided special breeding compartments (see Pl. III); otherwise the construction was very similar to that of the building of the previous year. Little difficulty from excessive heat was experienced in this house and this form of temporary outdoor insectary has been found admirably suited to this line of work. In the winter the roof is removed and the wire can be taken off the sides if desired, so as to leave absolutely natural conditions for the hibernating insects in the cages.

In the spring of 1910 another house (Pl. II, B) was built very similar to the one constructed the previous year. It covered 12 by 15 feet on the ground and was fitted with shelves on all sides and a large table in the center. (See Pl. IV.) The building was very commodious and convenient for work and was constructed for less than \$150.

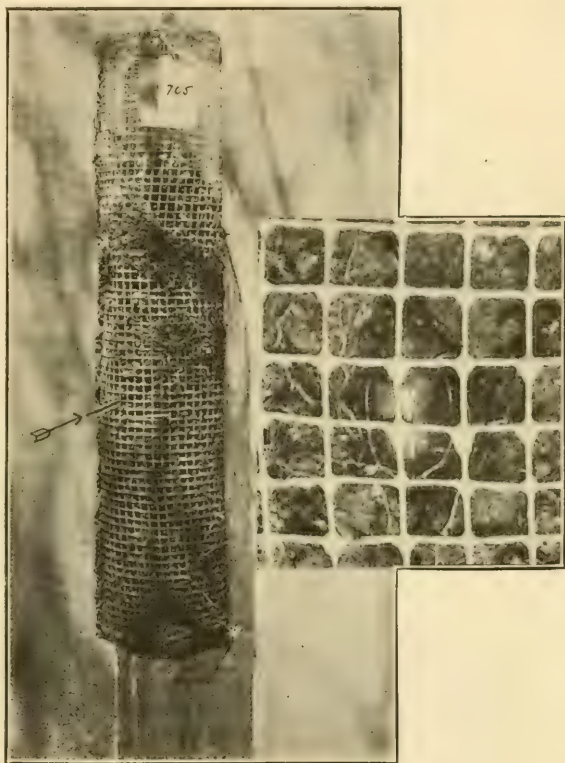


FIG. 10.—One of the cages shown in figure 9 that has been removed from the earth. Arrow shows the cavity where a *Calosoma* beetle hibernated; enlargement shows this beetle in the cage. (Original.)

METHODS OF REARING PREDACEOUS BEETLES.

Late in July, 1907, several beetles which were received in shipments from Europe were placed in jars with earth, one pair in each, and fed with caterpillars daily until they refused food, and entered the ground for hibernation. The earth was examined for eggs at the time new food was added, but only one pair reproduced. It was necessary to remove carefully the caterpillars that had been killed by the beetles each day, to keep the jars from becoming foul and to prevent the development of certain mites (*Tyroglyphus* sp.) which feed on decomposing animal matter, after which they attack the beetles and their larvæ, causing serious injury and sometimes death.

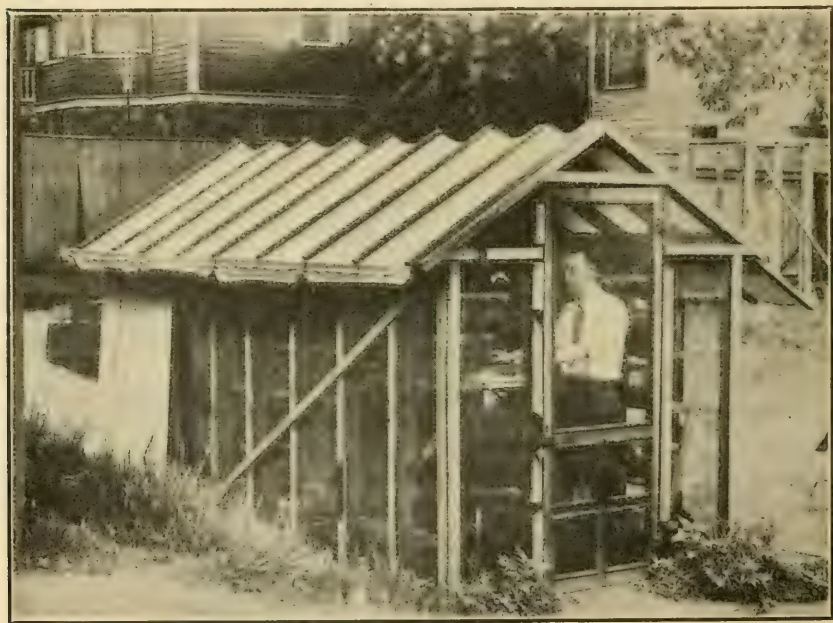
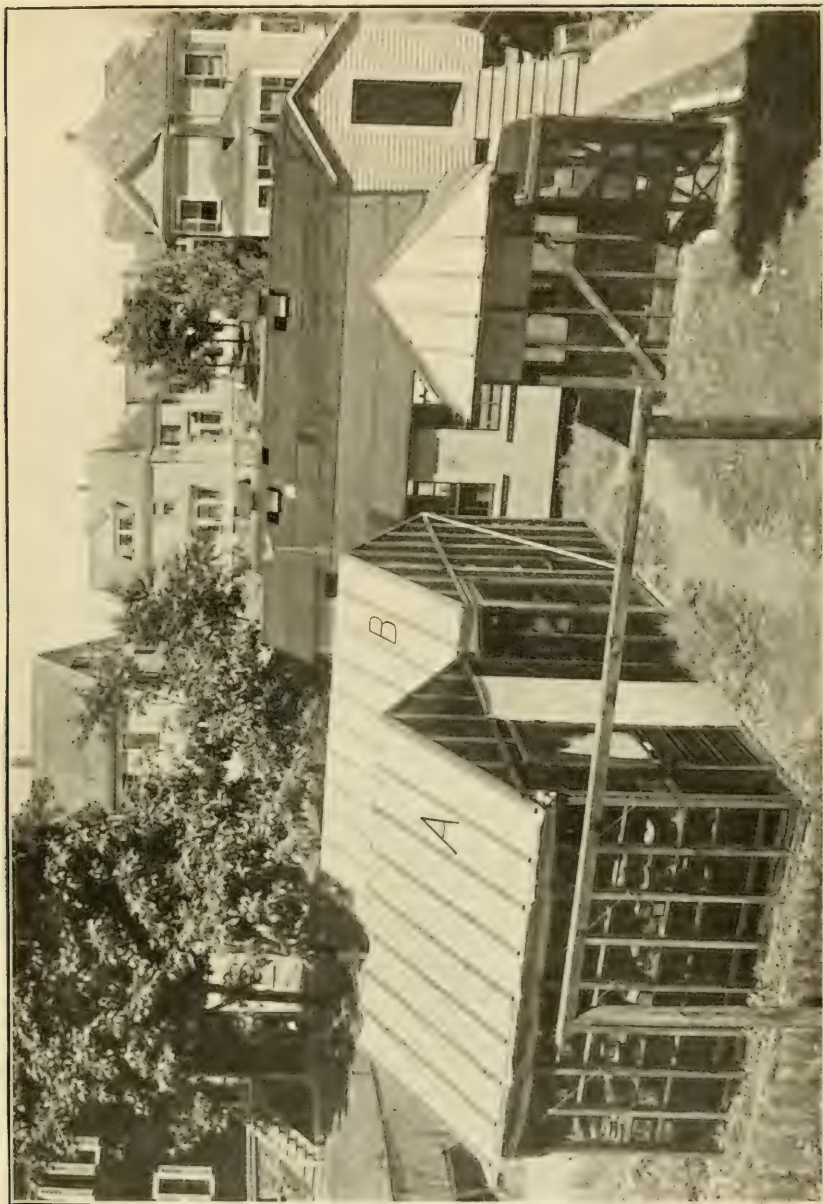


FIG. 11.—Outdoor insectary used for rearing *Calosoma* beetles. (Original.)

When eggs were found the beetles were transferred to another jar, which was given the same number as the one originally assigned, the first jar being kept under observation for larvæ.

The number of larvæ that hatch is usually taken as the index of the number of eggs deposited. It is impracticable to remove the eggs from the earth to make accurate counts, as they are easily injured in handling.

Several of the larvæ that hatched in August, 1907, were fed in separate jelly glasses containing a small quantity of earth, and later they were transferred to cages out of doors, to enter the pupal stage. A few pupated in earth in large jars, and some of these were placed in



PRESENT OUT-DOOR INSECTARIES FOR REARING CALOSOMA BEETLES.

A was built in 1909; B was built in 1910. (Original.)



INTERIOR VIEW OF INSECTARY "A," SHOWN IN PLATE II. (ORIGINAL.)



INTERIOR VIEW OF INSECTARY "B," SHOWN IN PLATE II. (ORIGINAL.)

a cellar during the winter, and young beetles were recovered in the spring. Other pupæ were removed from the jars and placed in out-of-doors cages. It was necessary to construct an artificial chamber in the earth in which to place each pupa, and this was done successfully in a few cases. A better plan is to allow the larva to make its pupal cell and not to permit the earth to be disturbed until the following spring.

The method above described of rearing these beetles was so satisfactory that in the spring of 1908 an attempt was made to rear larvæ for liberation in field colonies. By holding some of the shipments of beetles that arrived late in the summer of 1907 and placing them in large hibernation cages it was possible to have a stock of breeders ready for use as soon as desired in the spring.



FIG. 12.—Jars of earth containing eggs of *Calosoma sycophanta*. They have been placed in the sun to hasten hatching. (Original.)

The result of the work for the year was the rearing for colonization of 2,300 larvæ. During the following year this line of work was continued and 6,100 additional larvæ were placed in field colonies, and in 1910 6,380 were reared and liberated. When larvæ are being reared for liberation in field colonies it is desirable to hasten their development as much as possible. They are given an abundance of food and the jars containing eggs (fig. 12) are placed in the sun on cool days to accelerate hatching. The method of liberating larval colonies enables the species to become established over a much wider range and also gives it a better chance of surviving, owing to the varying conditions and locations in which it can be placed.

The beetles can be reared with fair success after some experience has been obtained in properly handling them. The food supply is one of the problems that causes considerable difficulty, especially early in the spring and late in the summer. Before gipsy moth larvæ are large enough to satisfy the ravenous appetites of the beetles, tent caterpillars have been used when it was possible to find them in sufficient numbers, while after the middle of July larvæ of the white-marked tussock moth, fall webworm, or any other caterpillars that could be collected have been used.

Each season the continuous services of one man have been required to collect caterpillars for beetle food, and at some times each year he has usually found it impossible to bring to the laboratory enough specimens to supply the demand. The amount of food consumed by beetles or larvæ is noted daily when the jars are examined, so that the feeding and rearing records can be observed at one time.

Owing to the carnivorous habits of the larvæ it is usually necessary to isolate them. This is especially true if detailed records are to be kept, or if they have become nearly full-grown. Hot weather stimulates their activity and appetite, and it is seldom possible to keep several large larvæ in the same jar during hot weather unless an abundance of food is supplied, and even then some of them usually succumb to the attacks of their comrades. The small larvæ do not attack each other so ferociously, but when some are practically helpless at the time of molting they fall an easy prey to the others. During the summer of 1909 and 1910, when large numbers were being reared for field colonies, it was impossible to isolate each individual, and as soon as hatching took place 10 to 15 were placed in a large battery jar containing earth and an abundance of food. If they were not allowed to remain more than three or four days before removal, the mortality was relatively low. Later in the season, after all the gipsy moth larvæ and pupæ had transformed in the field, as many as 200 larvæ were reared in box cages (Pl. V) having a surface area of 2 by 3½ feet. The weather was cooler at that time, and although a considerable number was killed, it did not render this method of rearing impracticable for use in late summer.

INVESTIGATION OF THE LIFE HISTORY OF CALOSOMA SYCOPHANTA.

One of the factors which renders this investigation somewhat difficult is the length of life of the adults. Only a small amount of data is available, because it is necessary to rear beetles in the laboratory in order to get the initial information. Many species of insects die as soon as the females have deposited eggs, or the males have fertilized the opposite sex, but this species, as well as others in the same genus, have an entirely different habit of life.

One female beetle received from Europe in July, 1907, was kept under observation at the laboratory for two years, so that the length of life may normally be considerably longer.

Nearly one-half of the beetles reared from eggs in 1907 that emerged from the earth in the spring of 1908 survived the summers of 1908 and 1909, and went into hibernation in the fall. This serves to illustrate the prolonged period throughout which accurate records must be kept, and the care with which the work must be conducted in order to secure correct data.

During the summer of 1910 measurements were made of 12 freshly-laid eggs and the same number of larvæ on entering each stage, and these notes are included in the descriptions of stages which follow.

THE EGG.

Twelve fresh eggs gave the following average measurements: Length, 5.2 mm., width, 2.4 mm. They are somewhat elliptical in form, with a slight taper toward one end. The color is white, with a faint yellowish tinge. They vary somewhat in size and form and before hatching often become somewhat kidney-shaped.

The time spent in the egg stage is from 3 to 10 days, and depends largely on the temperature. Careful observations on 2,000 eggs that were laid from May 15 to August 18, 1908, are summarized as follows:

TABLE III.—Duration of the egg stage in *Calosoma sycophanta*.

Egg stage.	Number of eggs in—				
	May.	June.	July.	August.	Total.
3 days.....			75	13	88
4 days.....		78	444	7	529
5 days.....		605	451	3	1,059
6 days.....	23	164	36	3	226
7 days.....	39	32			71
8 days.....	9	8			17
9 days.....	6				6
10 days.....	1	3			4

Average time in egg stage:	Days.
May.....	7
June.....	5.2
July.....	4.4
August.....	4

The eggs recorded as hatching in May were secured from females that were taken from hibernation in March, April, and May and fed in the laboratory. Oviposition seldom takes place under natural conditions in the month of May.

The average length of time spent in the egg stage, based on the hatching each month during the summer, was: May, 7 days; June, 5.2 days; July, 4.4 days; and August, 4 days.

The table also shows that 4.4 per cent of the eggs laid in 1908 hatched in 3 days, 26.4 per cent in 4, 53 per cent in 5, 11.3 per cent

in 6, 3.6 per cent in 7, 0.8 per cent in 8, 0.3 per cent in 9, and 0.2 per cent in 10 days.

That temperature has a predominant influence on the hatching of the eggs can not be doubted, and in this connection the following

TEMPERATURE RECORD-1909.

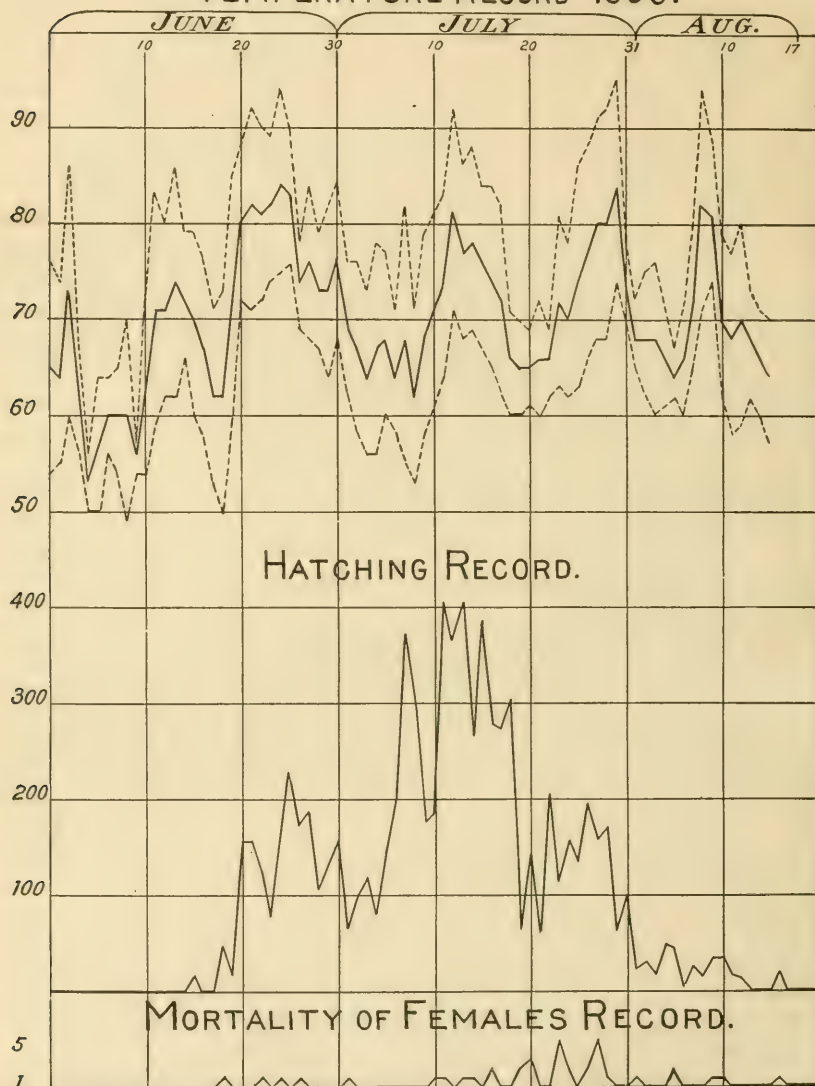


FIG. 13.—Diagram showing temperature record during the summer of 1909, the total egg-laying record, and the mortality of female *Calosoma* beetles for the same period. (Original.)

data, secured from the United States Weather Bureau at Boston, are of special interest.

The accompanying diagram (fig. 13) shows that during each period of high temperature there was an increase in the number of



BOX CAGES USED FOR REARING CALOSOMA LARVÆ LATE IN THE SUMMER

B. cover with fine-mesh screen, used in summer; *A.* showing coarse-mesh screen top, used after the larvæ have gone into the ground to transform and hibernate. (Original.)

eggs, as is indicated a few days later by the hatching record. This held true until the food supply began to fail late in July.

It will also be noted that the greatest mortality of females occurred about the last of July and indicates the relation between temperature, egg laying, food supply, and mortality.

NOTES ON HATCHING.

As the eggs are deposited in the earth by the female *Calosoma* beetles, it is difficult to secure exact data on the superficial changes that take place. The following note is of interest.

On August 2, 1907, two eggs laid that day were placed in earth in a jar, to observe the changes that take place previous to hatching. They were placed 1 inch below the surface of the earth and against the side of the glass, so that they could be easily seen. August 6, they were somewhat darker in color and had become slightly kidney-shaped. At 8 a. m., August 7, a larva had hatched from one egg and the other was dark gray in color, the segmentation of the body being plainly visible. At 2 p. m. the egg had hatched and the larva had moved away from the cavity. At 8 a. m., August 8, the larva which hatched first had made a tunnel to the surface of the ground, but had returned and was occupying the egg cavity. The other larva was not in sight. At 2 p. m. both larvæ were crawling on the earth in the jar in search of food.

Usually the eggs do not begin to assume a darker color until about 24 hours before hatching, although the change in outline and indications of segmentation are apparent before that time.

Infertile eggs sometimes become kidney-shaped, but usually the outline is more or less irregular and segmentation of the contents has never been observed. Such eggs usually contract to some extent in a few days. In most cases they become dark in color and gradually shrivel up and disappear in the earth.

To illustrate the care which must be taken in transferring the eggs of this insect, if it is necessary to do so, the following case is cited.

On July 23, 1908, a Riley cage, having a galvanized iron base containing earth, was examined for eggs. It contained a supply of *Calosoma* beetles which had been received from Europe some time previous. The insects were transferred to another cage and the earth was found to contain 253 eggs, which were placed in jars to observe hatching. One hundred and eighty-five larvæ developed from these eggs, or 73 per cent of the total number. Probably some of them were infertile, but allowing that this was the case, at least 20 per cent of the eggs must have been injured during the transfer.

EFFECT OF COLD ON EGGS.

As eggs are sometimes laid in August, it seemed desirable to test in a limited way their resistance to cold. Accordingly, on August 8, 1907, a jar containing a single egg in a quantity of earth was placed in cold storage, where the temperature was maintained at 26° F. This jar was packed in a box with several others, a small quantity of excelsior being used between them to prevent breakage and also to permit the contents to cool slowly. On August 22, two weeks later, the jar was removed to the laboratory, but the egg in question did not hatch.

Another jar, containing earth and two eggs, was placed in cold storage on the same date (August 8), but it was not removed until June 4, 1908, nearly 10 months later. An examination showed that the earth was very dry and the eggs had shriveled up.

Although few eggs were used in these experiments, the results seem to show that they will not hatch after being subjected to freezing temperatures.

THE LARVA.

The larvæ on hatching are nearly white, although slightly darker than the eggs. They remain in the chamber in which the egg reposed, and gradually grow darker until they become jet-black. About this time, if the weather is warm, they become active and make their way to the surface of the ground in search of food. The following description is made from a comparison of several larvæ after they had become fully colored and fed slightly. They molt twice and a brief description of each stage is given.

FIRST-STAGE LARVA.

Average length of 12 newly-hatched specimens, from base of mandibles to posterior end of last abdominal segment (not including anal proleg or caudal appendages), 9.3 mm. Average width at mesothoracic segment 2 mm.

The anal proleg is usually 1 mm. in length and the caudal appendages are about twice as long and taper gradually to the tips.

Color jet-black above; legs, antennæ, and mouth parts dark mahogany brown. If placed under a lens the body appears very dark brown, and the legs and mouth parts are of a somewhat lighter shade. Joints of antennæ, palpi, legs, and underside of body of a pearly color, except chitinous markings, which are jet-black. General outline of body fusiform. Antennæ longer than mandibles; maxillary palpi nearly as long as antennæ, tapering to tip of last joint; labial palpi stout, last segment cylindrical, truncate; prothorax wider than long. Second abdominal segment as wide as the first, body tapering quite abruptly beyond the fifth abdominal segment. Body provided with rows of lateral and ventral spines. Legs spiny. Caudal appendages bearing a few spines.

SECOND-STAGE LARVA.

Average length 15.5 mm. Average width 3.4 mm. Much stouter than first-stage larva. Body shining jet-black, mandibles and legs mahogany-brown, mouth parts lighter, nearly honey-yellow, dorsum of last abdominal segment and tip of proleg light

brown. Caudal appendages relatively shorter than in preceding stage, each provided dorsally with a stout but short protuberance on its inner third, which bears a stout bristle.

THIRD-STAGE LARVA.

More robust than in previous stage. Average length 25.8 mm. Average width 5.7 mm. Body shining black in color, mandibles, legs, mouth parts, antennæ, and lateral and ventral abdominal markings dark brown. Prothorax much wider than long, wider behind. Dorsum of last abdominal segment and anal proleg chestnut-brown. Dorsal abdominal plates nearly truncate behind, lateral margins of each raised and thickened. These margins more prominent on the last three segments. On the penultimate segment, each dorso-lateral margin forms a stout, blunt, overhanging fold, while on the last segment each margin is drawn out into a stout tooth, pointing backward.

Median dorsal line prominent on all segments except the last. Caudal appendages short, quite erect, with a large, stout dorsal tooth, and a small lateral tooth, both of which are provided with spines.

THE PROCESS OF MOLTING.

The larvæ are active and feed voraciously; during this time their bodies are greatly distended and the white portions of the integument render the insect quite conspicuous. Just before the molting begins they become sluggish and do not move about unless disturbed. The body shortens and becomes thicker than normal. By moving the head and posterior end of the body downward and toward each other at regular intervals the integument is ruptured along the dorsal line of all the thoracic segments. The head, mouth parts, and legs are gradually withdrawn and a pure white larva crawls from the old skin. Usually the sutures on the top of the head are broken as the larva makes its escape. The molting process requires but a few hours, and this is fortunate, as the larva is practically helpless while the transformation is being accomplished.

In nature the larvæ often molt under litter on the ground, but when they are feeding on caterpillars on the trees molting takes place in holes or cavities in the trees, among masses of gipsy moth pupæ, or even in crevices of the bark. It is probably true that many of the larvæ pass through the two molts without descending to the ground.

LENGTH OF TIME IN LARVAL STAGES.

The duration of time between the molts is influenced greatly by high temperatures and food supply. In the spring of 1908, careful records were kept of a number of larvæ which hatched from eggs deposited by beetles that were removed from hibernation in March and early April. One of the objects of the experiment was to determine the length of time required by larvæ that hatched early in spring to pass through their transformations, and further, to determine the possibility of such larvæ developing a brood of beetles which would become active and reproduce during the summer. A considerable

number of individuals in the experiment died owing to a scarcity of food and other causes, but the following nine records give the length of time which was spent in each larval stage and this may be considered as approximately correct for larvæ that hatch early in the season when the weather is cool and the food supply is somewhat restricted.

From the foregoing experiments data were secured regarding the length of time in each larval stage.

TABLE IV.—*Record of time passed in different stages by larvæ of Calosoma sycophanta hatched from eggs laid by beetles taken out of hibernation in March and April.*

No.	Date hatched.	First-stage larvæ.	Second-stage larvæ.	Third stage (until finished feeding).
	1908.	Days.	Days.	Days.
765A ¹	May 23	6	5	18
765A ³	May 24	8	2	19
765A ⁶	May 25	7	4	15
765A ⁷	May 26	6	9	13
765A ⁹	May 27	6	8	15
765A ¹¹	do.....	5	7	16
765A ¹⁴	do.....	5	8	14
765A ¹⁷	May 28	4	8	14
765A ²	do.....	4	8	15

Average length of time in each stage:	Days.
First larval stage.....	5½
Second larval stage.....	6½
Third or feeding stage.....	14½
Total time larvæ fed.....	26½

In order to check up this experiment and to determine the difference in time required for larvæ to develop during hot summer weather when food is abundant, another set of experiments was carried on with larvæ that hatched on June 20 and the results are tabulated as follows:

TABLE V.—*Length of time passed in different stages by larvæ of Calosoma sycophanta developed from eggs laid by beetles that emerged normally.*

No.	Date hatched.	First-stage larvæ.	Second-stage larvæ.	Third stage (until finished feeding).
	1908.	Days.	Days.	Days.
771D.....	June 20	2	3	9
771E.....	do.....	2	3	9
771F.....	do.....	2	3	9
771G.....	do.....	2	3	7
771H.....	do.....	2	3	9
771I.....	do.....	2	3	9
771J.....	do.....	2	3	9
771K.....	do.....	3	2	9
771L.....	do.....	2	3	9
771M.....	do.....	2	3	9
771O.....	do.....	2	3	9
771Q.....	do.....	2	3	9

Average length of life in feeding stages:	Days.
First larval stage.....	2
Second larval stage.....	3
Third larval stage.....	9
Total.....	14

An examination of this table shows that larvæ hatching late in June transformed much more rapidly than those noted in Table IV, the difference in the total average length of time being $12\frac{1}{2}$ days. Similar records based on a few experiments have been secured from larvæ that hatched at the laboratory late in July or during the first few days in August. The length of time spent in the larval stages was longer than the time required for the larvæ hatching in June. This is partly due to the difficulty of furnishing an ample food supply in August.

TIME OF APPEARANCE OF THE LARVA.

The date of the first appearance of the larva of this species in the field, of course, differs from year to year, depending on the season, and in colonies that have been liberated larvæ are seldom found as soon as the first ones hatch and begin feeding. The records of this investigation are rather fragmentary because of the relatively small number of adults that have been liberated in field colonies since the work began, and owing to the difficulty of making frequent examinations of any given colony and searching thoroughly enough to find the small larvæ. The earliest field records, however, are as follows: 1907, July 17; 1908, June 29; 1909, July 7; 1910, June 27. It should be stated that the first larvæ found in 1907 were nearly full grown, which explains partially the reason for their being found so late in July, although the season was not so early as that of the two following years. The latest records which we have of finding larvæ in the field are as follows: 1907, August 7; 1908, July 8; 1909, August 3; 1910, August 2. In the laboratory, where food was more abundant in early June and during the month of August than in the field, it has been possible to rear larvæ over a longer period of time. Aside from the food problem it has been possible to control to some extent temperature and moisture conditions, so that the time during which feeding experiments have been carried on has been prolonged.

HABITS OF THE LARVA.

Larvæ of this species secure food by searching for the caterpillars and pupæ of various lepidopterous insects. Undoubtedly some of those attacked are found on the surface of the ground or beneath leaves or litter, where they have sought shelter either for protection or pupation. The larvæ of this species, however, in addition to feeding in such situations are able to climb trees and devour their prey upon the trunks or branches. To this extent they may be considered arboreal in habit, although they are seldom found in any great quantities on trees which have smooth bark, as it is quite necessary for them to travel over uneven surfaces in order to secure a sure

footing. Not only do the larvæ secure a part of their prey in the trees, but they molt in crevices of the trunks and branches to a considerable extent. This habit is so general that it has been possible to determine quite accurately the dispersion of the species by examining trees for molted skins outside the areas where colonies have been liberated. This work can be done even after all larvæ have entered the ground for pupation, so that the time when satisfactory investigations can be made extends over the greater part of the summer. Trees in the gipsy moth infested sections which have been burlapped are favorite resorts for the *Calosoma* larvæ, as they find plenty of food available and are protected in a large measure from enemies that might destroy them. (See Pl. VI.) To determine the distance that larvæ of this species will climb, the following observation was made at West Gloucester, Mass. July 30, 1908, a number of larvæ was liberated in woodland and several were placed at the base of a red oak tree about 10 inches in diameter. Two of these larvæ immediately commenced climbing the tree. One ascended to a distance of about 10 feet and as no food was present it retraced its steps and returned safely to the ground. The other continued its journey up the tree. At a distance of 15 feet from the ground the bark became very smooth and offered little opportunity for the insect to obtain a safe footing. It continued to climb, however, until it reached a point about 25 feet from the ground, where it lost its hold on the bark and fell. There is no doubt that these larvæ often climb nearly to the tops of rough-barked trees, particularly white oak, in search of food. Several cases have been noted where molted skins were found at least 20 feet from the ground, and they have been observed in masses of pupæ on the underside of branches near the tree trunk. The climbing habit of the larvæ is of great importance, as it increases the opportunity for the development and usefulness of the species.

DISTANCE TRAVELED BY THE LARVA.

Inasmuch as young larvæ of this species must be able to find suitable food in order to develop, the question of their ability to travel is one of great importance. It seemed desirable to test this matter and plans were made and apparatus constructed for the purpose. A young larva was taken which had just hatched, and a record kept of its travels until it died, no moisture or food being supplied throughout the experiment. In order to secure this record a small table 3 feet 8 inches long by 2 feet wide was equipped with spools at each end near the top so that a roll of paper could be reeled across the top of the table by turning the spools. (See fig. 14.) Beneath this paper was placed a piece of stiff wrapping paper which extended beyond the sides

of the paper connected with the reels, and the edges were bent upward in such a manner as to prevent the escape of the larva from the sides of the table. The paper on the reels consisted of ordinary wrapping paper 18 inches in width. The larva was placed in the center of the table and the record of its travels was made with a lead pencil. The experiment was begun at 8.30 a. m., June 18, 1910, and was conducted by Mr. C. W. Collins, with the assistance from time to time of various



FIG. 14.—Method of securing data on the distance traveled by larvae of *Calosoma sycophanta*. (Original.)

members of the laboratory force. It was necessary to carry on this experiment continuously until the larva died, and as it remained active for 72 hours shifts of men were used so that there was no break in the record. The larva traveled far more rapidly than was expected and it became necessary from time to time to substitute a fresh roll of paper in place of the one containing the record. In all 11 rolls were used and careful measurements indicate that during its life the larva

traveled 9,058 feet or 1.71 miles. (See fig. 15.) It might be of interest to state that the insect was active the greater part of the time, and that the greatest speed for a 4½-hour period was 4.9 feet per minute, and that during the first 24 hours the average rate of travel was 3.69 feet per minute. After the second 24 hours the rate of travel decreased gradually, and during the last 12 hours the larva spent considerable time at rest. During the course of the experiment the larva lost about 0.11 grains, or a little more than one-third of its original weight. This experiment shows the remarkable vitality possessed by these larvæ, and indicates that under any conditions they would be able to survive for several days and travel a considerable distance before succumbing from the effects of hunger. The conditions under which the test was conducted were, of course, abnormal, and it is not presumed that a larva of this species would travel as great a distance as

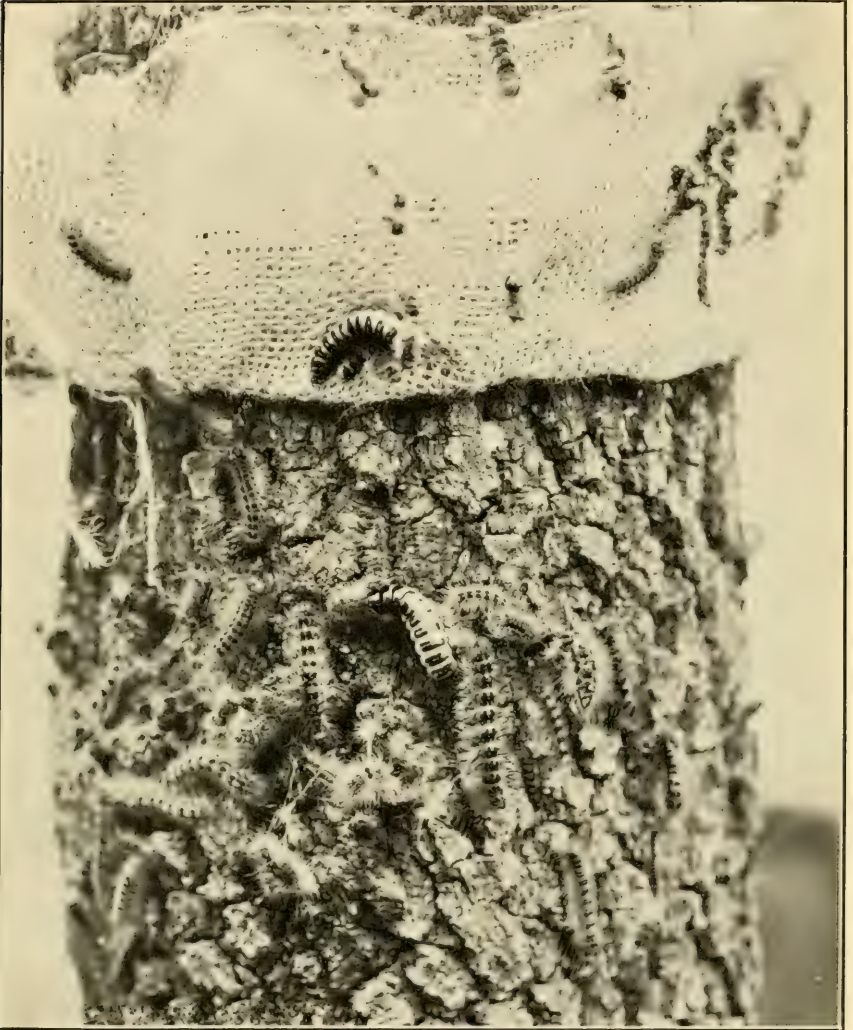


FIG. 15.—Roll of paper showing record of distance traveled by larva of *Calosoma sycophanta*. (Original.)

that indicated in the record. It should be said, however, that in certain respects the test was unfavorable for the larva, owing to the fact that no moisture whatever was supplied and that it traveled on a dry surface and at a temperature which made rapid evaporation possible.

FEEDING HABITS OF THE LARVA.

The larvæ of this species appear to feed both by day and night, but their activity in this direction is greatly stimulated if the weather is hot. As a rule the caterpillars are attacked from the side or in the middle of the back, and if they are hairy specimens the favorite place seems to be between the segments where the larvæ can more readily pierce the integument with their sharp mandibles. Newly hatched larvæ of *sycophanta* are able successfully to combat equally well all



LARVÆ OF CALOSOMA SYCOPHANTA FEEDING ON GIPSY MOTH CATERPILLARS UNDER BURLAP.

Photograph taken at Pine Banks Park, Malden, Mass., 1910. (Original.)

caterpillars regardless of size. After the body wall of a caterpillar has been cut, the *Calosoma* larvæ feed upon the juices and apparently devour a large amount of the fat body of their prey. The entire internal tissues of the caterpillar are seldom eaten, and many specimens are injured to such an extent that they eventually die, and thus more caterpillars are prevented from transforming than are actually eaten. The pupæ of *Lepidoptera*, especially those which are destitute of a cocoon, suffer greatly from the inroads of the larvæ of this insect. In fact, so far as the gipsy moth is concerned, it is probable that the destruction of the pupæ is fully as great as that of the larvæ. Of course the pupæ are practically unprotected and are in a helpless condition, so that they fall an easy prey to the hungry beetle larvæ. Usually the larva forces its mandibles through the gipsy moth pupa, between the segments. The hole is greatly enlarged and the contents of the pupal case are removed before the larva passes on to another pupa. The entrance holes made by the *Calosoma* larva in the pupa of the gipsy moth are characteristic. (See Pl. VII.) They are always irregular in outline and sometimes extend nearly the entire length of the pupal case. It is very easy to distinguish these holes from others made by parasites. Fresh gipsy moth pupæ are possibly more subject to attack than those from which the adults are more nearly ready to emerge, but there seems to be only a relatively small amount of discrimination used by the larva in selecting its victim. Where pupæ are massed on the trunks of trees under branches or in any sheltered position an extremely favorable opportunity is presented for the larvæ of this beetle to operate. In fact, in colonies where the beetles are numerous it is not uncommon to find one or more of the larvæ in every large mass of pupæ examined. (See fig. 16.) Usually it is necessary to disturb the pupæ, otherwise the beetle larva will be overlooked as it secretes itself beneath the silk and old pupal cases which form the mass and feeds from beneath on the living pupæ. Examinations that have been made during the last two years directly in and throughout the territories surrounding many of the beetle colonies which have been liberated in the field, have revealed the presence of large numbers of pupal cases that have been destroyed by the beetle larvæ, although it is seldom possible to find anything like the number of molted skins of the beetle larvæ that might be expected from the number of gipsy moth pupæ that have been destroyed. In field colonies, the larvæ of *sycephanta* have been found attacking and killing adult females of the gipsy moth. In one case the end of the abdomen of the female was pierced and in spite of the large amount of fine hairs with which the insect is provided and which must be distasteful to such a small predator as a beetle larva, the internal portion of the abdomen including most of the eggs was devoured and of course the death of the moth resulted.

FOOD OF THE LARVA.

The larvæ of *Calosoma sycophanta* feed chiefly on lepidopterous caterpillars and pupæ. It may be that coleopterous or other larvæ or pupæ which live on or near the surface of the ground are destroyed, but we have no definite data bearing on this matter. Apparently the larvæ prefer large caterpillars or pupæ which have a considerable amount of fatty matter in the body cavity. This makes gipsy moth larvæ and pupæ particularly suitable as food for these predaceous larvæ. In rearing work at the laboratory only a few species have been furnished and these have been selected on account of their



FIG. 16.—Larva of *Calosoma sycophanta* feeding on gipsy moth pupæ on trunk of tree, North Saugus, Mass., July, 1907. (Original.)

abundance and the ease with which they could be collected. Forest and American tent caterpillars (*Malacosoma disstria* Hbn. and *M. americana* Fab.), gipsy moth larvæ (*Porthetria dispar* L.), brown-tail moth larvæ (*Euproctis chrysorrhæa* L.), and fall webworms (*Hyphantria textor* Harr.) have been used to the greatest extent and all of these species except the last mentioned have been attacked with equal avidity. It is probable that fall webworm larvæ, on account of their

small size, the dense hairy covering of the body, and the character of their internal contents are not a preferred host of this species, and we have observed that beetle larvæ thrive better on more robust specimens.

Aside from the species already mentioned, *sycophanta* has fed freely in captivity on all species of caterpillars offered, among which may be mentioned: *Papilio polyxenes* Fab., *Callosamia promethea* Dru., *Estigmene acrea* Dru., *Halisidota caryæ* Harr., *Alypia octomaculata* Fab., *Catocala* sp., *Heterocampa* sp., *Heterocampa guttivitta* Walk., *Gluphisia septentrionalis* Walk., and *Heterocampa leucostigma* S. and A.

EXPERIMENTS IN FEEDING LARVÆ.

AMOUNT OF FOOD REQUIRED.

During the summer of 1908 two series of experiments were conducted for the purpose of determining the number of caterpillars which would be eaten by larvæ of *Calosoma sycophanta* from the time of hatching until ready for pupation. Each larva was placed in a jelly glass with a small amount of earth, and caterpillars were supplied daily and a record kept of the number eaten. The first set was begun May 23, with a few larvæ, and records were kept of numerous others which hatched from that time until May 28. The eggs from which these hatched were deposited by beetles that were removed from hibernation during March and April. Sixteen larvæ were fed in this experiment and the amounts which were eaten will be found in Table VI.

TABLE VI.—Food eaten by larvæ of *Calosoma sycophanta*.

Date hatched.	Brown-tail moth caterpillars, fourth stage.	Gipsy moth caterpillars.			Total.
		Fourth stage.	Fifth stage.	Sixth stage.	
1908.					
May 23.....	28	25	36	6	95
May 24.....	12	13	28	28	81
Do.....	14	12	14	35	75
May 25.....	5	19	38	10	72
May 26.....	5	15	35	21	76
May 27.....	5	13	34	30	82
Do.....	6	14	38	20	78
Do.....	5	20	18	24	67
Do.....	30	14	28	8	80
May 26.....	16	21	40	16	93
May 27.....		22	36	21	79
May 28.....	31		28	23	82
Do.....		23	48	11	82
Do.....		26	42	15	83
Do.....		18	37	21	76
Do.....		25	37	27	89

On June 19 a similar experiment was begun, and between that date and July 1 larvæ were added, so that, in all, 19 individuals were fed from the time of hatching until they were full grown. These larvæ developed from eggs laid by female beetles that came out of hibernation normally in June, 1908, while those in the previous set were the progeny of females that had been removed from hibernation and were fed in the laboratory under unnatural conditions.

TABLE VII.—*Food eaten by larvæ of Calosoma sycophanta.*

Date hatched.	Total food, sixth-stage gipsy moth larvæ.	Date hatched.	Total food, sixth-stage gipsy moth larvæ.
1908.		1908.	
June 19.....	33	June 20.....	52
Do.....	39	Do.....	37
Do.....	32	Do.....	48
June 20.....	43	Do.....	49
Do.....	43	Do.....	43
Do.....	45	Do.....	37
Do.....	31	June 21.....	45
Do.....	45	Do.....	37
Do.....	40	Do.....	40
Do.....	37	Average.....	41

The larvæ in Table VI required on an average 28 days to complete their feeding, while in Table VII only 14 days were necessary. The number of caterpillars consumed in the first was considerably greater than in the second series. This was largely due to the fact that those in the second series were fed entirely on sixth-stage gipsy moth caterpillars, while the other lot was furnished with smaller caterpillars for food. The average given in Table VII is probably the more correct index of what takes place under natural conditions in the field, and it shows that on the average a single larva of *Calosoma sycophanta* will destroy at least 41 full-grown gipsy moth caterpillars. The results shown in these two tables illustrate how impossible it is to attempt to accelerate the development of certain species of insects. While some of the parasitic forms will reproduce as long as a proper food supply is maintained and the temperature kept above a point where they seek hibernation, it has been impossible to induce the beetles of this genus to depart from their fixed habit of developing only one generation in a single year.

EXPERIMENTS IN FEEDING CALOSOMA LARVÆ WITH DISEASED GIPSY MOTH CATERPILLARS.

The question is often asked whether the larvæ of this species are susceptible to the disease commonly known as the "wilt," which each year destroys enormous numbers of gipsy moth caterpillars in badly infested colonies. In order to make a test, a limited number of experiments was carried on both in 1908 and 1909. The results in 1908 seemed to indicate that the larvæ suffered very little from this trouble, and in 1909 the tests were continued, but unfortunately the larvæ were fed in jelly glasses which proved too small to allow them to move freely after they became nearly full grown. The final results were similar to those secured the previous year, but it was thought best to make a further test in 1910. Ten larvæ that hatched on June 30 were fed in individual jars with gipsy moth caterpillars that showed signs of the "wilt." Feeding continued until July 15. One larva



PUPÆ OF THE GIPSY MOTH THAT HAVE BEEN DESTROYED BY THE LARVÆ OF CALOSOMA SYCOPHANTA.
Note the irregular holes, which are characteristic. (Original.)

died; 9 entered the ground and pupated, but 3 of these died in the pupal stage, so that only 6 adults emerged. The amount of food consumed was less than the amount usually eaten by a beetle larva of this species and averaged 30 full-grown gipsy moth larvæ.

The result of this experiment shows conclusively that this species suffers little if any from the "wilt." An examination of the rearing records indicates that the percentage of survival in these experiments compares favorably with that in those tests where healthy caterpillars are offered for food. In fact it seldom happens that 90 per cent of the larvæ that hatch can be reared to the pupal stage in confinement, and the loss of 30 per cent of the pupæ is not surprising when it is understood that pupation took place in jars containing only a small amount of earth, which rendered the transformation very difficult. The record of the feeding experiments of all the larvæ of *sycophanta* that hatched in 1907 shows that 15.5 per cent of the gipsy moth caterpillars furnished as food died from disease.

In field colonies it is quite common to find *Calosoma sycophanta* in localities where enormous numbers of gipsy moth larvæ and pupæ are dying from the "wilt" disease, and frequently larvæ of the *Calosoma* beetle are found feeding on the pupæ and on the caterpillars of the gipsy moth in masses which are badly diseased. Only one case has been observed of a dead *Calosoma* larva showing symptoms of the "wilt" disease, and the evidence in this instance was not at all conclusive. If the *Calosoma* beetles were susceptible, there is every reason to believe that at least some of the field colonies would have been practically exterminated by disease, but the results of repeated examinations in the field show exactly opposite conditions.

RESULTS OF FEEDING TO CALOSOMA LARVÆ CATERPILLARS FROM SPRAYED OR POISONED AREAS.

Owing to the practice of spraying for the purpose of controlling the gipsy moth, a method which has come into very general use during the past few years, fear has been expressed that the *Calosoma* beetles or their larvæ might be destroyed by feeding upon caterpillars that had devoured the poisoned foliage. During the past two summers attempts have been made to test this matter in the laboratory, but in the season of 1909 this work had to be discontinued on account of the large number of other experiments which was then being conducted.

In 1910 a series of experiments was planned—the idea being to spray a small area of low growing sprouts in which gipsy moth caterpillars were abundant, and to feed these caterpillars to the larvæ of the *Calosoma* and keep a close record of the result. The experiments were begun with the larvæ of *sycophanta* which hatched June 30, 10 individuals being used in the tests. From the beginning of the

experiments great difficulty was experienced in securing a sufficient supply of poisoned caterpillars. In areas that were thoroughly sprayed practically all the caterpillars died in a few days, but it was usually possible to find a few caterpillars that were apparently in a perfectly healthy condition. This was undoubtedly due to the fact that they had been feeding on foliage which was not thoroughly sprayed, or from which the poison had been washed by rain. Before the experiments were half completed it was impossible to secure caterpillars that had fed on poisoned foliage; hence, the results given are far from being conclusive. Two of the *Calosoma* larvæ, each of which ate 34 gipsy moth caterpillars, passed through their transformations and developed as perfect beetles, but the others died before reaching the pupal stage.

Observations in the field would indicate that where areas badly infested with the gipsy moth are sprayed, the *Calosoma* beetles will probably migrate to other sections where caterpillars are abundant. As it is impossible for the larvæ of the *Calosoma* to migrate, it is probable that if a large number of eggs was laid by the beetles a considerable proportion of the larvæ resulting would die from starvation on account of the lack of a sufficient number of caterpillars to furnish ample food supply. Undoubtedly some of the larvæ would be able to obtain sufficient food to pass through their transformations; hence there is relatively little chance of completely destroying this species as a result of arsenical spraying.

It is evident, however, in making liberations of *Calosoma* beetles in the field, that this should be done in localities where spraying will not be attempted, in order that the insects may have every opportunity to develop and increase. This policy has been followed, and in only a few cases has the spraying of the territory where the beetles were liberated been permitted, and then only when it became apparent that serious defoliation would result unless the work was done. It is evident that as soon as the species becomes firmly established and dispersed over a large area, as is now the case in a portion of the infested district, spraying will have little effect on the number of specimens which will develop.

EXPERIMENTS IN FEEDING GIPSY MOTH PUPÆ TO CALOSOMA LARVÆ.

The larvæ of *Calosoma sycophanta* are very fond of gipsy moth pupæ and destroy large numbers of them in the field. In order to determine how many are eaten, a series of experiments was begun with 10 *Calosoma* larvæ that hatched July 11, 1910. They were fed separately upon gipsy moth pupæ until they were fully developed and descended into the ground to pupate. The average number of pupæ which each beetle larva consumed was 13. In the course of this experiment it appeared that more female pupæ

were eaten than males, and another test was begun by Mr. Collins to determine whether this preference was constant.

Ten larvæ that hatched July 21 were isolated in jars and furnished with 3 male and 3 female gipsy moth pupæ, which number was increased as the larvæ grew and became more voracious. In this experiment each larva averaged to destroy 12 pupæ, 17 per cent of which were males and 83 per cent females. In one case an adult female gipsy moth was eaten by a *Calosoma* larva when pupæ of the gipsy moth of both sexes were present in the jar.

In order to check this experiment three localities were visited by Mr. J. V. Schaffner, jr., and Mr. H. L. MacKenzie for the purpose of collecting the molted skins of *Calosoma* larvæ and making counts of the number of male and female gipsy moth pupæ that had been destroyed.

The first locality selected, in the Lynn woods, was badly infested with caterpillars earlier in the season, and the larvæ of *syncophanta* had been found plentiful. All the trees had been banded with tanglefoot, but owing to the fact that a considerable number of eaten pupæ, as indicated by the empty pupal shells, was found above the sticky bands, it is probable that the bands had been applied rather late in the season. Trees were also examined in two other localities several miles from the Lynn woods, viz. at Mount Hood, Mass., near the Melrose and Saugus line, and at Pine Banks Park, Malden, Mass. In these two localities there was no tanglefoot on the trees. A few of the trees at Pine Banks Park were burlapped and most of them had been sprayed. The trees were climbed and a record kept of all male and female gipsy moth pupæ that had been eaten by the *Calosoma* larvæ. The results for 20 trees examined showed that 24.5 per cent of the gipsy moth pupæ eaten were males and that 75.5 per cent were females. These data correspond very closely with those secured under laboratory conditions and indicate that the preference of the larvæ for female pupæ is pronounced under field conditions. The effect of the preference of the *Calosoma* larvæ for the female pupæ of the gipsy moth is thus very apparent and indicates that the benefit which is likely to accrue from this species may be greater than was at first anticipated.

EXPERIMENT IN FEEDING EARTHWORMS TO LARVÆ OF *CALOSOMA*.

In order to determine whether the larvæ of *Calosoma syncophanta* will feed on other than insect food, 5 newly hatched individuals were supplied with earthworms, as they had proved an acceptable diet for several species of *Carabus* received from Europe. All the *Calosoma* larvæ died in the first stage, and none of the earthworms was eaten, 4 of the larvæ lived 4 days, and 1 died at the end of 2 days. This

experiment served to indicate the approximate length of time which young larvæ can survive without food, although a more detailed experiment of this sort follows.

STARVATION EXPERIMENT APPLIED TO LARVÆ OF CALOSOMA SYCOPHANTA.

Early in the spring of 1908 a series of experiments was carried on, using 5 beetle larvæ in each stage in order to determine how long they would remain alive and active without food.

August 3, 1908, 5 newly hatched beetle larvæ were placed in jars of earth without food; 2 larvæ died in 3 days, 2 in 4 days, and 1 in 5 days.

August 3, 1908, 5 larvæ that had just passed the first molt were placed in jars of earth without food; 1 larva died in 6 days, 3 in 7 days, and 1 in 9 days.

August 6, 1908, 5 larvæ that had just passed the second molt were placed in jars of earth without food; 2 larvæ died in 8 days, 1 in 10 days, and 1 in 16 days.

The remaining larva, after having been confined, without food, in a jar for 9 days, was offered fall webworms. It consumed 5 larvæ in 3 days, but at the end of that time died.

This experiment shows that the older *Calosoma* larvæ are able to survive without food for a longer period than the younger ones. In nature they will probably live longer than the time indicated, as they would be able to obtain considerable moisture which would help to prolong life.

In order to determine how late in the summer it is possible to plant larval colonies of *Calosoma sycophanta* successfully, two experiments were tried in 1908.

On August 7, 1908, 100 *Calosoma* larvæ that had passed the second molt were liberated in woodland at Waltham, Mass. No gipsy moth caterpillars were present at the time, but a few newly hatched brown-tail moth larvæ were feeding on the trees. No native caterpillars were observed at the time the *Calosoma* planting was made.

In the spring of 1909 the trees in this colony were burlapped and examinations were made at intervals throughout the summer. In September a molted larval skin of the *Calosoma* was discovered on one of the trees, and the following summer (1910) beetles, larvæ, and molted skins were found, showing that some of the *Calosoma* larvæ in the original planting had developed and that the strength of the introduced colony was increasing.

In order to test the matter under still less satisfactory food conditions, a colony of 100 third-stage *Calosoma* larvæ was liberated in the oak woodland at Tewksbury, Mass., August 12, 1908. The larvæ were placed at the base of each of six oak trees, the foliage of which was being eaten by small brown-tail moth caterpillars. This colony

was burlapped and examined the same as was the one at Waltham, Mass., but no traces of *Calosoma* beetles have since been found.

The results in these field colonies show that the beetle larvæ are sometimes able to develop even when the food supply is very scanty.

EXPERIMENT TO DETERMINE WHETHER CALOSOMA LARVÆ WILL HIBERNATE DURING THE WINTER.

A *Calosoma* larva which hatched August 7, 1907, and became nearly full grown September 7, was placed in a cavity 6 inches below the surface of the earth in a galvanized-iron cage out of doors.

May 19, 1908, the cage was taken up and a dead *Calosoma* beetle was found in the cavity where the larva had been placed. The death of the insect was caused by the pressure of the earth upon it. The weather was cool from the time the larva was buried until the date of removal, hence this experiment shows that the insect does not normally, and probably can not, hibernate in this stage.

PLACING CALOSOMA LARVÆ IN COLD STORAGE TO DETERMINE ABILITY TO WITHSTAND COLD.

The following experiment was tried to test the ability of larvæ of this species to withstand cold.

August 8, 1907, two lots, each containing 4 *Calosoma* larvæ (2 newly hatched larvæ, 1 larva 6 days old, and 1 full-grown larva), were sent to cold storage, where a temperature of 28° F. was maintained. The smaller larvæ were placed in separate vials which contained about 3 inches of earth, and plugged with cotton, while the full-grown larvæ were placed in jelly glasses containing about 2 inches of earth.

August 22, 1907, one lot was removed from storage. The 2 newly hatched larvæ were dead on top of the earth. The other 2 larvæ were in the ground and were apparently dead.

August 27, 1907, another examination was made. All larvæ failed to revive, and the experiment was closed.

June 4, 1908, the second lot was removed from storage. The earth was very dry in both vials and jelly glasses. All larvæ were dead.

These results indicate that the larvæ will not survive cold storage, but if they are full grown and are subjected to a gradual reduction of temperature they will pupate and transform to beetles before becoming dormant.

METHODS USED IN REARING CALOSOMA LARVÆ.

During the progress of the work many experiments have been tried in order to ascertain the best methods of rearing the *Calosoma* larvæ. If only a few specimens are desired for study the use of a small jar

for each individual larva provides an excellent way of handling them, but when large numbers are to be reared for field liberation it is desirable to adopt some method that will save as much time as possible and at the same time insure the development of most of the specimens. Owing to the cannibalistic habits of the *Calosoma* larvæ in all stages it is necessary to furnish large quantities of food if many are to be fed in the same container. If these conditions are maintained a considerable number of the larvæ can be fed in the same jar or cage until after the second molt.

Early in August, 1908, 5 newly hatched larvæ were placed in a Fiske tray (fig. 17) without earth. They fed in this tray and molted

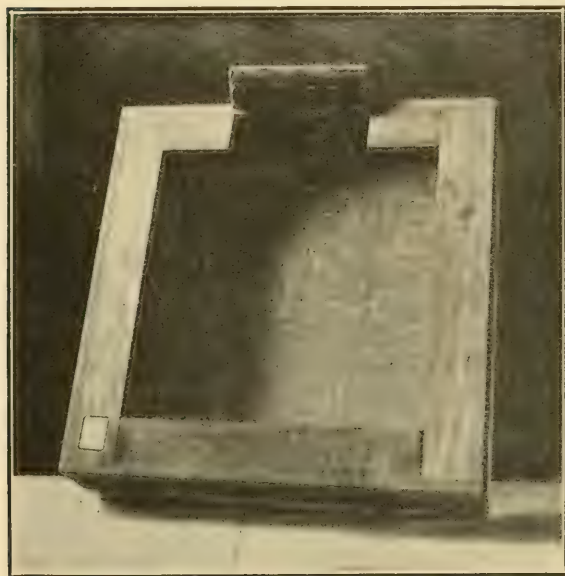


FIG. 17.—A "Fiske tray" for feeding gipsy moth caterpillars. A section at the top has been sawn out and bent back to show the tanglefooted band which prevents the caterpillars from escaping. (Original)

twice before showing any inclination to attack each other. After this time 3 of the larvæ were killed by their comrades and assimilar experiments gave the same result it is apparent that they can not be kept longer in close quarters.

Another experiment was tried using a large Fiske tray 5 feet long and 2 feet wide. Ten *Calosoma* larvæ 2 days old were placed in it with food and a quantity of leaves. Eight larvæ passed through the first molt successfully,

6 through the second—these were left in the tray—and at the time of the final examination only 1 remained. Apparently some of them grew faster and killed the others while searching for food.

In another test where 5 small larvæ were placed in a small Fiske tray and were removed after they had molted once, all survived.

The facts thus obtained have been made use of in rearing larvæ for field liberation. Ten to fifteen *Calosoma* larvæ were placed in a large battery jar containing earth, and plenty of food was supplied. The larvæ were removed usually after molting once, but in some cases they

molted twice in the jars. The mortality for the season of 1909 was 10 per cent of the 8,280 larvæ which were fed in this way, and for 1910 it reached 12 per cent of the 8,720 larvæ that hatched. It is interesting to compare these figures with those for the year 1908 when a smaller number of larvæ was fed individually in jelly glasses provided with cheesecloth covers. A considerable number of larvæ escaped by forcing their way through the covers and in all 13.8 per cent of the total for the year (2,854) were either lost or died. This shows that the improved covers used on jars the following years and the experience gained in handling the larvæ have resulted in reducing the mortality.

Since the work began, July 23, 1907, nearly 20,000 *Calosoma* larvæ have been cared for and most of these have been liberated in the field.

In August, 1909, a considerable stock of *Calosoma* larvæ was on hand at the laboratory, and as it seemed advisable to feed and carry them through the larval stages and hibernation where they could be under direct observation they were placed in large box cages (see Pl. V) set in the ground. These were 2 by 3½ feet in size, and were provided with a fine wire-netting bottom so that the larvæ could not escape. The earth in the cages was 15 inches deep. Several cylinders of galvanized iron wire, 17 inches in diameter, were also constructed for the same purpose and were sunk in the ground and later stocked with larvæ and food. (See fig. 18.) These cylinders were lined on the inside with mosquito netting and the tops and bottoms were made of the same material.

One thousand three hundred and eight second and third stage *Calosoma* larvæ were placed in these cages or cylinders between July 30 and August 27, 1909, and of this number 210 larvæ, or 16.6 per cent, were killed by their comrades. The food supply was of necessity very poor in quality, especially after the middle of August when gipsy moth larvæ and pupæ that had been held in cold storage were furnished, many of which were in a badly decomposed condition.

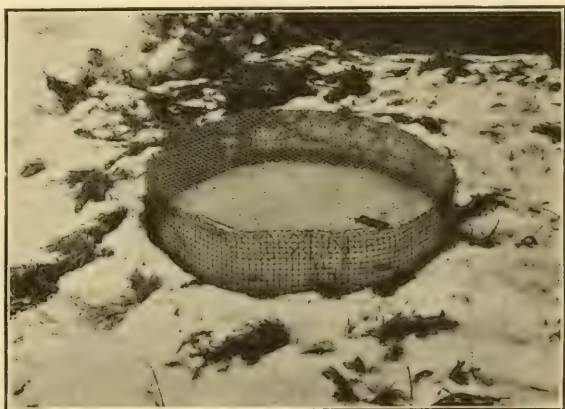


FIG. 18.—Wire-screen hibernation cylinder where larvæ of *Calosoma* were fed in August, 1910. Photographed February, 1911. (Original)

The following year (1910) 1,224 larvæ were placed in similar cages or cylinders between July 26 and August 16, and only 5 per cent were killed by their comrades. Some cold storage gipsy moth pupæ were supplied, but they were in very good condition for feeding to the *Calosoma* larvæ.

THE DISTANCE CALOSOMA LARVÆ PENETRATE THE GROUND TO PUPATE.

The distance which the larvæ of this species penetrate the ground for the purpose of forming their pupal chambers varies greatly, and seems to be governed largely by the character of the soil, and the amount of moisture which it contains.

Few observations have been made on *Calosoma* larvæ that feed under natural conditions, as it is a difficult matter to find hibernating beetles in the ground, even in our most prosperous colonies.

It is probable that if the ground is hard and dry—as is usually the case in midsummer—the larvæ are not able to descend for more than a few inches below the surface. In one of our cages during the summer of 1909 a larva burrowed under a board and formed a pupal chamber beneath it, so that a living pupa was readily exposed by lifting the board. The cage experiments at the laboratory do not offer typical data on this point, for the reason that it is necessary to fill the cages with fresh earth when they are set in the ground early in the summer, so that the soil is not as compact as it would be under natural conditions. In 1908, several larvæ pupated in jars partly filled with earth. As a rule the pupal cavities were made at or near the bottom of the jar, and these were from one-half an inch to 3 inches below the surface.

A record of 20 *Calosoma* pupæ—12 males and 8 females—which made cavities, during the fall of 1908 and 1909, shows that they penetrated from 4 to 8 inches below the surface in outdoor cages. The average distance for males was $6\frac{2}{3}$ inches and for females $7\frac{1}{4}$ inches. Seven males and 5 females went to the bottom of a cage which contained 8 inches of soil. Under natural conditions the *Calosoma* larvæ probably will not burrow more than from 4 to 5 inches into the ground before making the pupal chamber. Thus the insect must remain considerably above the frost line during the winter. In some rare cases *Calosoma* larvæ have successfully pupated on the surface of the ground, and in nature they may sometimes pupate under the leaves or vegetable mold in forest areas.

The distance that the *Calosoma* larvæ go into the ground to form their pupal chamber corresponds very well with the distance which the *Calosoma* beetles will burrow for the purpose of going into hibernation, and several records bearing on this point will be given later under the head of hibernation of the beetles.

THE PUPA.

THE PUPAL CHAMBER.

The pupal chamber or cell is formed by the full-grown larva. As soon as feeding is completed the larva becomes somewhat shorter and thicker, makes its way into the ground, and by means of burrowing and moving the body about, forms the chamber in which to pupate.

The pupa rests in this cavity (fig. 19) on the dorsum, where it remains until the beetle emerges.

DESCRIPTION OF PUPA.

Length 25 mm., width at first abdominal segment 12 mm. Color pale yellow. Head depressed, only a small portion of the pronotum being visible from above. Dorsal part of thoracic segments smooth, shining. Lateral edges of first abdominal

segment rounded behind. On the second to sixth segments, inclusive, the lateral edges are thickened and dark brown in color, and protrude slightly over the stigmata. The former are slightly hollowed out in front and bluntly toothed behind. The segments following are not thickened laterally. A thick brush of brown hairs is present on the dorsal part of the first five abdominal segments, also a smaller one on the eighth segment;

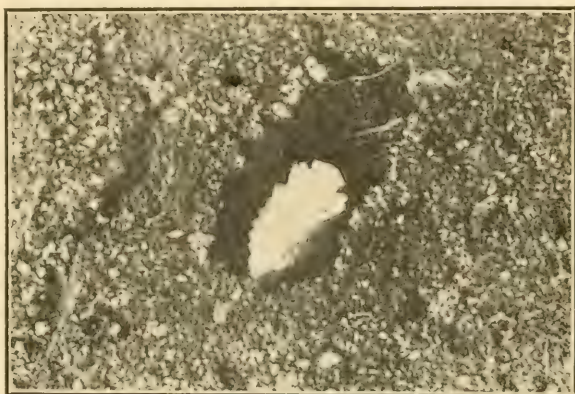


FIG. 19.—Pupa of *Calosoma sycophanta* in cavity in the earth.
(Original.)

sometimes less prominent ones occur on the sixth and seventh segments. Spiracles somewhat protected by lateral brushes. Mouth parts, antennae, wings, and legs folded beneath the head. Hind pair of legs extending to the tip of the abdomen. Wings extending beyond the fourth abdominal segment.

EXPERIMENTS WITH THE PUPE OF *CALOSOMA SYCOPHANTA*.

Several experiments have been tried by removing pupæ from their natural pupating cavities and placing them in jars or artificially constructed cavities in order to determine whether they can be safely handled in this stage. In a number of cases no disastrous results followed their removal, and they can be safely treated in this way, provided the artificial cavity in which they are placed remains intact, so that no lumps of earth or other substances fall in upon the pupæ and thus prevent the normal emergence of the beetles. As a rule it is difficult to secure these conditions with any degree of cer-

tainty, and it is therefore better to avoid disturbing the larva after it has descended to form the pupal cavity.

During the fall of 1907 it seemed desirable to ascertain if it was possible for *Calosoma* larvæ which hatched from eggs laid late in the season to enter the pupal state and so remain during the winter.

Ten pupæ were used in this experiment, and were treated in three different ways. One lot was placed in galvanized-iron cages, another in mosquito-netting cages out of doors, and the third lot pupated in jars, which were placed in a cool cellar during the winter.

EXPERIMENT IN WINTERING CALOSOMA PUPÆ IN GALVANIZED-IRON CAGES.

The galvanized-iron cages were made in the form of a cylinder, 4 inches in diameter and 24 inches long, and were sunk into the ground 20 inches. The ends of the cylinders were covered with mosquito netting.

On September 6, 1907, 5 pupæ were removed from the pupal cavities in the jars in which they had previously transformed, and on the following day another specimen was secured, and each of the 6 was placed in a separate cage at depths of 4, 6, 8, 10, and 14 inches below the surface, an artificial cavity at these depths being made in the soil.

May 19, 1908, the cages were examined, and it was found that all the *Calosoma* pupæ had transformed to beetles. Two females were alive, although one had been partly crushed by the settling of the earth in the cylinder, while 2 males and 1 injured specimen, which could not be determined as to sex, were also found.

Cages of this type proved impractical for hibernation experiments.

EXPERIMENTS IN WINTERING CALOSOMA PUPÆ IN WIRE-NETTING CAGES.

Two pupæ were used in the experiments with wire-netting cages, but the results with one of these was not determined owing to an accident.

The cage consisted of wire mosquito netting, which was attached to the trunk of a tree, and extended about a foot below the surface of the ground, the top being covered with the same material. On September 6, 1907, the *Calosoma* pupa from which the only record was secured was placed in a cavity made about 4 inches below the surface.

May 18, 1908, this cage was dug up and a live male beetle found in the cavity.

EXPERIMENTS IN WINTERING CALOSOMA PUPÆ IN A COOL CELLAR.

Jars containing 4 *Calosoma* pupæ were removed to the cool cellar of the laboratory on September 20, 1907, and early in October they were transferred to another cellar where the temperature was slightly above freezing during the winter, and which was very damp.

On March 4, 1908, two jars were removed from the cellar and kept in the laboratory at room temperature. In one of these the fully formed beetle could be seen in a cavity at the side of the jar. On April 13 this beetle, which proved to be a female, emerged and fed, and on April 16 the remaining beetle, also a female, came to the surface and began feeding.

The other two jars were not removed until June 9. A dead beetle which had previously emerged was found on the surface of the ground in one of them, while in the other a live male was found in the cavity.

To check these experiments, three jars, each containing a pupa, were placed in cold storage September 7, 1907. One pupa had transformed in a jelly glass $1\frac{1}{2}$ inches below the surface of the earth. This glass was put into a battery jar containing 1 inch of earth and enough more was added around the sides of the jelly glass to make the earth level in both jars. The second pupa had transformed in earth, in a jelly glass, and the third pupa, in a battery jar, was located in a cavity 2 inches below the surface of the earth. On June 5, 1908, all the jars were removed from cold storage. The pupa in each case was dead. In one of the glasses, and in the battery jar, the earth was very dry. The death of the pupæ was due presumably to the sudden reduction in temperature to about 28° F., no rise in temperature being noted during the entire period of storage.

These experiments indicate that the *Calosoma* beetles normally emerge from the pupa in the fall and hibernate in the adult form during the winter, as this was the case in the first set of experiments, even though the temperature was reduced considerably below normal.

LENGTH OF TIME SPENT BY *CALOSOMA SYCOPHANTA* IN THE PUPAL STAGE.

It is somewhat difficult to ascertain the exact length of time spent in the pupal stage, for the reason that several days elapse from the time the larva stops feeding until actual pupation takes place.

In the season of 1910 notes were made on eight larvæ that pupated in jars of earth in such positions that their movements could be observed. The length of time from cessation of feeding until pupation actually took place was from 7 to 15 days, the average time being $10\frac{1}{2}$ days. In one case a larva pupated on July 27, 1908. On August 2 the legs were becoming darker in color, and on August 4 a female beetle emerged. The elytra were still soft, and some little time was required for the beetle to become fully developed and active. A few days later it entered the ground and formed a cavity, where it remained for hibernation. In two other cases from 10 to 11 days were required for the pupa to pass through that stage.

On August 20, 1909, a fully formed pupa was found in a cell under a board in one of the out-of-doors cages, and careful notes were made

daily by Mr. S. S. Crossman. It was white, and evidently had just pupated. Mr. Crossman's memorandum contains the following notes:

August 23: Legs, eyes, and mouth parts have become pale pink in color.

September 3: Eyes nearly black, tips of mandibles black.

September 6: Mouth parts black, legs and tip of abdomen becoming darker in color. The body is of a dirty cream color.

September 8: Eyes and mandibles black. Legs and antennæ brown. Tip of abdomen darker in color.

September 9: Legs and antennæ growing darker; tibiae and tarsi black; clypeus brown.

September 10: The entire pupa is much darker to-day.

September 11: Beetle emerged at 8.15 a. m. The elytra are pale brown in color. At 12 m. they had become brownish green, and at 3 p. m. metallic green, which is characteristic of newly emerged beetles. The body is still soft, and the beetle has not left the cell.

September 13: Beetle left pupal cavity early this morning.

The length of time in this stage will be governed largely by the temperature as it will be noted that the pupæ first cited transformed to adults in about one-half the time required by the one last mentioned. A good set of records was secured in 1910 and they are probably typical for jar experiments. When the larvæ pupate in the ground, doubtless the time required is somewhat greater.

The records of 10 pupæ, 6 males and 4 females, ranged from 12 to 15 days, the average being 13.4 days.

THE ADULT OR BEETLE.

EMERGENCE OF CALOSOMA BEETLES IN THE SPRING.

Only a few records were kept in the spring of 1908 of the emergence of *Calosoma* beetles which developed from pupæ in the fall of 1907, as most of the specimens reared were used for experiments to test the ability of the beetles to hibernate and the cages were dug up before the time of normal emergence.

In the spring of 1909 the time of emergence for 16 males and 17 females that transformed from pupæ in the summer of 1908 ranged from June 8 to 21, the average time being June 13. The first two weeks in June were unusually cool for the season of the year, the temperature averaging much lower than in 1908.

A similar record of 512 beetles in the spring of 1910 showed that the emergence took place from May 11 to June 28, the average date being June 2.

Hibernation is so closely related to emergence that it is considered at this point.

HIBERNATION OF CALOSOMA SYCOPHANTA.

In the summer of 1907 it was found that as soon as the food supply was reduced, the *Calosoma* beetles became inactive, and if given an opportunity they went into the ground and remained in a somewhat

dormant condition. The specimens that were under observation that year could not be expected to behave in a normal manner, because they were received about July 20, and were collected possibly three weeks before, so that they were deprived of food during the height of the feeding season.

They went into hibernation from August 12 to September 16, 1907, although some would probably have entered earlier if a large supply of food had not been offered them.

This species always burrows into the ground to spend the winter, unless the soil is so hard that this is impossible. Occasional specimens may remain beneath leaves or mo'd in wooded areas, but we have no data to show that this habit is normal, as is the case with some of the species of *Carabus*. The hibernation cages used have been supplied with earth which was rather loose and offered an excellent opportunity for the insects to burrow.

The cavities range from 2 to 15 inches, but some have been found 20 inches below the surface of the ground. *Calosoma* beetles seldom go below the frost line. They remain in these cavities until warm weather, when they come to the surface of the ground in search of food.

The weather has a most important bearing on the emergence in the spring, but in general it may be said that *Calosoma* beetles will seldom be found before June 1, which is a week or more after most of the gipsy moth larvæ have hatched.

Table VIII shows the average dates of entering hibernation.

TABLE VIII.—Average dates of entering hibernation by *Calosoma sycophanta*.

Year.	Number of beetles.		Age of beetles.	Average date males entered hibernation.	Average date females entered hibernation.
	Males.	Females.			
1908.....	11	11	Old.....	Aug. 17	Aug. 15
.....	12	14	Young.....	July 14	July 16
1909.....	103	83	Old.....	Aug. 8	Aug. 5
1910.....	38	39	do.....	Aug. 1	July 31

This table indicates that the males and females enter hibernation at practically the same date; while there is considerable variation in different years, the average is about August 1.

The date when the beetles went into hibernation in 1907 was much later than normal, as the specimens were not received from Europe until late in July and were given a liberal supply of food. The record of beetles for the next year is more nearly correct, as the only ones included were those that had been used in reproduction operations during the season. Old beetles are those that have entered hibernation for the second time, while young beetles are those that pass through

hibernation in the pupal cavity. The date when young beetles go into hibernation depends almost entirely on the time when the eggs are laid and whether the larva has an abundance of suitable food. July 14 and 16 were the averages dates for males and females for the year 1908.

TABLE IX.—Average date of emergence of *Calosoma sycophanta* from hibernation.

Year.	Number of beetles.		Age of beetles.	Average date males emerged from hibernation.	Average date females emerged from hibernation.
	Males.	Females.			
1908.....	6	7	Old.....	June 4	June 3
1909.....	34	39	do.....	June 8	June 10
	15	17	Young.....	June 13	June 13
1910.....	261	251	do.....	June 1	June 3
	58	46	Old.....	June 6	June 7

The date of emergence depends on the weather and on the location in which the beetles spend the hibernating period.

During the spring of 1909 the weather was very cool in May and in early June, and as a consequence the average dates of greatest emergence extended from June 8 to 13, while the following year the average extended from the 1st to the 7th of June.

From the table above, which contains the records of 734 specimens, it will be noted that there is very little difference in the date of emergence of males and females. A greater discrepancy is shown between the old and young beetles, but this is probably more apparent than real, as the earth was very loose in some of the cages, so that the beetles hibernated very deep in the ground, and hence their emergence was delayed. The earliest date of emergence is May 8 and the latest June 29.

In general it can be said that most of the emergence will take place in the field during the first week in June, beetles having been found on or before June 4 during the past three years.

MORTALITY OF CALOSOMA BEETLES DURING HIBERNATION.

During the winter of 1908-9, 35 per cent of the old male beetles and 25 per cent of the old female beetles died, and the following winter 31 per cent of the old male beetles and 27 per cent of the old female beetles died. Of the young beetles 22 per cent of the males and none of the females died during the winter of 1909-10. This data would seem to indicate that about one-third of the old beetles die during the winter. The mortality of the young beetles in hibernation on the average is probably less than 20 per cent.

These results were secured from beetles that hibernated under favorable conditions. It was necessary to conduct a number of

careful experiments in order to determine the best cages to use for the hibernation of these insects, and the results of these various tests are given in order that others who may desire to carry on similar work may profit by this experience.

EXPERIMENTS IN WINTERING CALOSOMA BEETLES IN GALVANIZED-IRON CAGES.

In the fall of 1907 it became necessary to place as many beetles as possible in hibernation cages so that a supply would be available for the rearing work of the following spring, as well as to make a thorough test of the ability of this species to withstand a New England winter. Several styles of cages were used for the purpose, and as it was desired to place them out of doors a number of cages was constructed of galvanized iron. They were made in the form of a cylinder, 20 inches long and 4 inches in diameter. A flange was turned on the upper and lower edges so that wire netting could be attached by means of a wire which encircled the cylinder at the base of each flange. They were set in the ground so that 2 or 3 inches of the cage protruded. Beetles were placed in these cylinder cages in September, 1907. The following spring it was found that these cages were very unsatisfactory for the purpose, as two-thirds or more of the insects placed in them had died during the winter. The chief trouble appeared to be due to the freezing and thawing of the earth in the cylinder, which rendered it very compact, and in many cases the beetles were crushed in their hibernation cavities or were unable to make their way through the wet soil early in the spring. Fortunately, several other styles of cages were used and better results with them were secured.

EXPERIMENTS IN WINTERING CALOSOMA BEETLES IN WIRE-SCREEN CAGES.

Several hibernation cages were made of galvanized-wire screen having a $\frac{1}{4}$ -inch mesh. This material is commonly used for screening cellar windows, and it forms an excellent cage. (See fig. 9, p. 18.)

Several experiments were also tried in using cages made of mosquito netting sunk into the ground and attached on one side to the trunks of trees. The results with these cages were satisfactory, but as the wire rusted badly it is impossible to use them for more than one season, so that the cage previously mentioned is more desirable.

EXPERIMENTS IN WINTERING CALOSOMA BEETLES IN BOX CAGES.

For hibernating large numbers of beetles use has been made of tight wooden boxes about 24 inches deep, provided with galvanized iron wire bottoms and covers, and these have proved satisfactory. (See fig. 8, p. 17.)

EFFECT OF REMOVING CALOSOMA BEETLES FROM HIBERNATION EARLY IN THE SPRING.

In the spring of 1908 several series of experiments were conducted in order to determine whether it is possible to remove *Calosoma* beetles from hibernation before the normal time, feed them under laboratory conditions, and be able to produce more than one generation of beetles a year. If this work could be carried on it would be of considerable biological interest and would increase the number of specimens that could be liberated in field colonies. In order to make these tests, several cages containing hibernating *Calosoma* beetles were removed from the ground March 4, 1908. The weather was very cold, and it was necessary to cut through from 7 to 14 inches of frost before the cages could be taken out. They were brought to the laboratory and allowed to warm up gradually with the expectation that the beetles would emerge from the earth in a short time, begin feeding, and deposit eggs. As a matter of fact, they emerged slowly, and after reaching the top of the earth in the cages they were placed in jars of earth and furnished with caterpillars which were being reared in the laboratory. Similar lots of beetles were removed from hibernation in April and May. The results of the experiments indicate that it is possible to remove beetles in this way, but an extra generation can not be developed during the summer. The larvæ did not become full grown much sooner than those that developed from eggs laid at the normal time.

FEEDING HABITS OF THE ADULTS.

The adults climb trees, travel out on the branches and twigs, and occasionally cling to the leaves while searching for caterpillars. If disturbed, they fall to the ground and instantly seek shelter under leaves or rubbish. Gipsy-moth and brown-tail moth caterpillars are attacked while the *Calosoma* beetles are in the trees, the favorite point of attack on the caterpillar being in the middle of the back. They are firmly grasped by the sharp mandibles of the beetle, and after many frantic efforts on the part of the victim to escape the integument is ruptured and the beetle proceeds to feed on the contents of the body. Very rarely does the gipsy-moth or the brown-tail moth caterpillar escape without serious injury, and this never occurs if a firm hold is once secured by the predatory *Calosoma*. Occasionally beetles will be seen carrying the caterpillars in their jaws.

LENGTH OF FEEDING PERIOD OF THE ADULTS.

The active feeding period of *Calosoma* beetles extends from the date the beetles emerge in the spring from hibernation until about two weeks before they enter hibernation in the fall. But little food is consumed during the two weeks immediately preceding entrance

into hibernation, and, as a rule, the beetles are rather sluggish in movements.

Many records have been secured, but the most typical are perhaps the ones obtained during the summer of 1910. Twelve pairs of *Calosoma* beetles were kept under observation, being fed in jars. There were 4 pairs of old beetles, the same number of young beetles, old males and young females, and old females and young males.

The earliest emergence was noted on May 25 and the latest on June 5. Feeding was completed between July 5 and August 9. The shortest feeding period was 32 days and the longest 66 days, with 50 days as an average.

The feeding period corresponds fairly well with that of the caterpillars of the gipsy moth. The beetles do not emerge at quite as early a date in the spring as that upon which the gipsy moth caterpillars hatch, and in the fall the gipsy moth has transformed and deposited its eggs before the *Calosoma* beetles seek hibernation.

FOOD OF THE ADULTS.

The food of the adult beetles is similar to that of the larvæ. Each year some of the *Calosoma* beetles have been fed on native lepidopterous larvæ and none of the species offered was rejected by them.

If the weather is cool in the early summer, the beetles remain on the ground, usually under leaves or litter, and sally forth on the first warm days in search of food. As soon as caterpillars become scarce, late in July or early in August, the beetles feed less and spend most of the time beneath the ground, soon burrowing down to form the hibernating cell.

Elaborate experiments have been conducted each year since 1907 to determine the number of gipsy-moth caterpillars that are destroyed by these predaceous beetles and a mass of data has accumulated from which typical results have been selected. The most complete series of experiments was conducted during the year 1910, and the results are summarized in Tables X, XI, and XII.

Sixth-stage tent caterpillars and gipsy-moth caterpillars were used, as they were of about the same size and offered a fairly uniform ration on which to base the average amount of food consumed.

TABLE X.—Feeding records of 4 pairs of young *Calosoma* beetles, 1910.

Pair No.	Emerg- ed from hi- berna- tion.	Ceased feeding.	Sixth-stage caterpillars consumed.		
			Tent.	Gipsy moth.	Total.
4804.....	May 26	July 15	76	165	1241
4805.....	..do..	..do..	135	39	174
4806.....	..do..	July 13	120	226	1346
4807.....	..do..	July 8	60	35	95

¹ Females laid eggs.

TABLE XI.—Feeding records of 4 pairs of old *Calosoma* beetles, 1910.

Pair No.	Emerg'd from hiberna- tion.	Ceased feeding.	Male died.	Female died.	Sixth-stage caterpillars consumed.		
					Tent.	Gipsy moth.	Total.
4808.....	May 25	July 20	July 25	July 12	102	204	³ 306
4809.....	do.	do.		July 24	95	194	³ 289
4810.....	May 26		¹ July 7	² July 11	57	237	³ 294
4811.....	June 3			² July 5	149	179	³ 328

¹ Added male No. 4811.² Record discontinued.³ Females laid eggs.TABLE XII.—Feeding records of *Calosoma* beetles, 1910.

Pair No.	Emerged from hiberna- tion.	Ceased feeding.	Female died.	Sixth-stage caterpillars con- sumed.			
				Tent.	Gipsy. moth.	Salt marsh.	Total.
Old males, young females:							
4812.....	May 26	July 18		110	106		216
4813.....	June 4	Aug. 9		87	97	4	188
Young males, old females:							
4814.....	June 3	Aug. 2	Aug. 3	104	357		¹ 461
4815.....	June 5	July 18		105	125		² 230

¹ Female laid eggs.² Female laid eggs; did not hatch.

These tables show, on the average, that the old *Calosoma* beetles consume more food than young ones. This is undoubtedly due to the greater reproduction which is common with the former.

The average for the old beetles was 328 caterpillars and for the young beetles 239, while the average for all the pairs given in Tables X, XI, and XII is 272 caterpillars. This is a fair average, as nearly as can be determined, of the number of caterpillars that the *Calosoma* beetles will actually destroy. In the field probably the number would be increased, as feeding under natural conditions would undoubtedly stimulate activity and appetite.

In addition to the large number of experiments that has been carried on to determine the amount of food that will be eaten by *Calosoma* beetles that emerge from hibernation at the normal time, several series were conducted with beetles that were taken from hibernation in March, April, and May. These beetles did not become active and begin feeding for a considerable time after the cages were removed to a warm room in the laboratory, but as small caterpillars of various species, particularly brown-tail moth larvæ that were being fed in the laboratory, were used for food, large numbers were destroyed before midsummer. Most of these caterpillars were small and as soon as the *Calosoma* beetles became active large numbers were required to satisfy their hunger.

The average number of small brown-tail moth caterpillars eaten by 3 pairs of *Calosoma* beetles removed April 9, 1908, was about

2,000 caterpillars per pair of beetles. This indicates that the number of caterpillars consumed, and hence the amount of benefit derived, depends to a considerable extent on the size of the prey, and, further, that if gipsy moth caterpillars should be scarce in any locality a great number of the smaller native species would be destroyed.

EFFECT OF FEEDING DISEASED GIPSY MOTH CATERPILLARS TO CALOSOMA BEETLES.

Among the feeding experiments begun in July, 1907, was one to test the effect, on the health of the *Calosoma* beetles, of feeding them diseased gipsy moth larvæ. In the other feeding experiments where gipsy moth larvæ were used it was found that 15½ per cent of them died from the disease known as the "wilt." A single pair of *Calosoma* beetles was fed, from July 23 to August 14, with caterpillars which showed pronounced symptoms of the disease. Twenty-one larvæ were eaten, 3 were so badly injured that they died, and the remaining larvæ supplied to the beetles in the jar died from disease. These beetles ate slightly less than in the case of other pairs that were fed healthy food, but showed no bad effects and went into hibernation at the same time as the other pairs. Unfortunately they were placed in a galvanized-iron cage and died before spring, as was also the case with other pairs that were wintered in the same kind of cages. The death of these beetles may, therefore, be attributed to the unsuitability of the cage rather than to action of the diseased food consumed.

July 8, 1910, an experiment was started with 2 pairs of old beetles. One pair ate voraciously; the female oviposited freely, and died August 16 following. The other pair ate very little, no eggs were laid, and both beetles went into hibernation in August.

All the experiments conducted would seem to indicate that the beetles of *Calosoma sycophanta* are not susceptible to the "wilt" disease.

Each year large numbers of the gipsy moth caterpillars die in the feeding jars from this disease, and if it were seriously destructive to the *Calosoma* beetles or their larvæ it would long ago have been necessary to give up the experimental and rearing work.

EXPERIMENTS IN FEEDING CALOSOMA BEETLES WITH GIPSY MOTH CATERPILLARS FROM SPRAYED OR POISONED FOLIAGE.

Several attempts have been made to determine whether adult *Calosoma* beetles are injured or killed by feeding on gipsy moth caterpillars taken from sprayed trees. In 1910 an attempt was made to test this matter, and a small area of brush and scrub growth near the laboratory was sprayed with arsenate of lead and the gipsy moth caterpillars collected later from time to time, in order to make a test. The experiments were begun on June 17, 1910, and gipsy moth caterpillars from this poisoned area were used for food until July 13,

with the exception of the few days from June 19 to June 26, when caterpillars from other and unsprayed localities were used. One male *Calosoma* died July 18 and a female died on July 29. The other beetles went into hibernation at the normal time. The experiment indicates that neither of the beetles that died was injured by the food supply. It is probably true that most of the caterpillars taken from the sprayed area had no great amount of poisoned leafage in their bodies, otherwise they would have died. Under natural field conditions *Calosoma* beetles of this species may migrate from sprayed areas, either immediately after spraying or as soon as caterpillars commence to show the effects of the poison, as the caterpillar food supply is greatly reduced and the beetles naturally seek localities where caterpillars are plentiful.

EXPERIMENT IN FEEDING CALOSOMA BEETLES ON BEEFSTEAK.

Calosoma beetles that were placed in cold storage August 15, 1908, were removed in March and May, 1909, and as the supply of gipsy moth caterpillars was very limited at that time they were furnished with beefsteak for food. In each case the beetles fed on it for about a week, but selected caterpillars in preference whenever they were available. At the end of a week they seemed to become tired of steak and seldom fed on it. These observations show that this species will probably eat raw meat to a limited extent if forced to do so by hunger, but that caterpillars are always preferred and selected for food whenever they can be found.

STARVATION EXPERIMENTS WITH CALOSOMA BEETLES.

May 26, 1910, 2 pairs of young *Calosoma* beetles that were pupæ in the fall of 1909 and 2 pairs of old *Calosoma* beetles that were received from Europe in the summer of 1909, and hibernated in cages in the laboratory yard, were placed in jars of earth, 1 pair in each, as soon as they came out of hibernation, to determine how long they could live without food.

TABLE XIII. —Starvation experiment to determine the length of time the adult *Calosoma sycophanta* can live without food.

<i>Calosoma sycophanta</i> .	Date emerged from hibernation.	Date male died.	Length of time male lived without food.	Date female died.	Length of time female lived without food.
	1910.	1910.		1910.	
Young pair.....	May 26	June 26	1 month.....	July 9	1 month 13 days.
Do.....	do.....	June 29	1 month 3 days....	July 5	1 month 9 days.
Old pair.....	do.....	July 17	1 month 21 days....	June 26	1 month.
Do.....	do.....	June 30	1 month 4 days....	(1)	(1)

¹ This female, after living without food for 1 month and 21 days, was offered several full-grown gipsy moth caterpillars July 17, and ate 2 in 10 minutes. The next day a male was added, copulation was attempted several times, but without satisfactory results. The female died July 30 without depositing eggs. During the 12 days the pair were in the jar 33 sixth-stage gipsy moth caterpillars were eaten.

The beetles in the above experiments remained a portion of the time under the earth during the first two weeks, but from that time until they died were always to be seen on the surface at any hour during the day.

Table XIII shows that the *Calosoma* beetles can survive for a month without food, and under natural conditions in the field, where more or less moisture is present, the length of time would no doubt be increased. Apparently old beetles can withstand starvation better than young beetles, and males appear to die sooner than females, under these conditions, but several exceptions are to be noted in the table. The number of specimens under consideration is not large enough to give more than a general idea of the hardy nature of this species.

A field colony of *Calosoma* beetles was liberated in 1907 with the idea of testing their ability to survive on a very limited food supply. On August 28, 50 specimens, 25 of each sex, were liberated in woodland in Peabody, Mass. These beetles had been received from Europe during the month and had been supplied with very little food since they arrived. At the date of liberation there were no gipsy moth caterpillars in the field and very few pupæ. Occasionally a native caterpillar would be seen, but they were rare in the vicinity of the colony. Under these conditions it appeared possible to make a thorough test.

The colony was examined the next spring and summer. On July 8 a *Calosoma* larva was found, showing that reproduction had taken place. This would indicate that the species can survive under very unfavorable conditions.

ASSEMBLING EXPERIMENTS.

In the summer of 1910 it seemed desirable to carry on a few experiments to determine, if possible, the distance that the male *Calosoma* beetles are attracted by the females, and for this purpose a cage was set up in the salt marshes between Lynn and Revere, Mass. This cage (fig. 20) was about 10 inches square and 12 inches high. The sides were covered with mosquito netting and underneath a narrow board which extended around the cage, and which was beveled on the underside, was stretched a thin sheet of rubber, which was attached in such a way that beetles from the outside could gain admission but could not escape. Within this cage was placed a wire cylinder containing both old and young females which had just emerged from hibernation.

June 13, 1910, this cage trap was set up in the marsh at a point one-half mile or more distant from any trees. It was attached to a pole about 8 feet high, and in the inner cage were 2 young and 2 old

females, with plenty of gipsy moth caterpillars for food. Beetles of this species were known to be present in the nearest wooded areas.

The trap was visited every three or four days until July 4, to see if males had been caught, and to supply food to the females. It was then visited about every ten days, until the middle of August, when it was removed. No males were caught during the experiment.

Another experiment, using the same kind of a trap, was begun at Wilmington, Mass., June 15, 1910. No specimens of *sycophanta* were known to be present within 2 miles of the point where the trap was placed. Four young and two old female beetles were put into the cage, and it was set up in a pine tree 45 feet from the ground. (See Pl. VIII.)

Marked males were then liberated at distances of one-half mile and 1 mile, respectively, north, south, east, and west of the trap, 1 old and 6 young beetles being released at each of the eight stations.

None of the males or females in this experiment had had an opportunity to come into contact with the oppo-

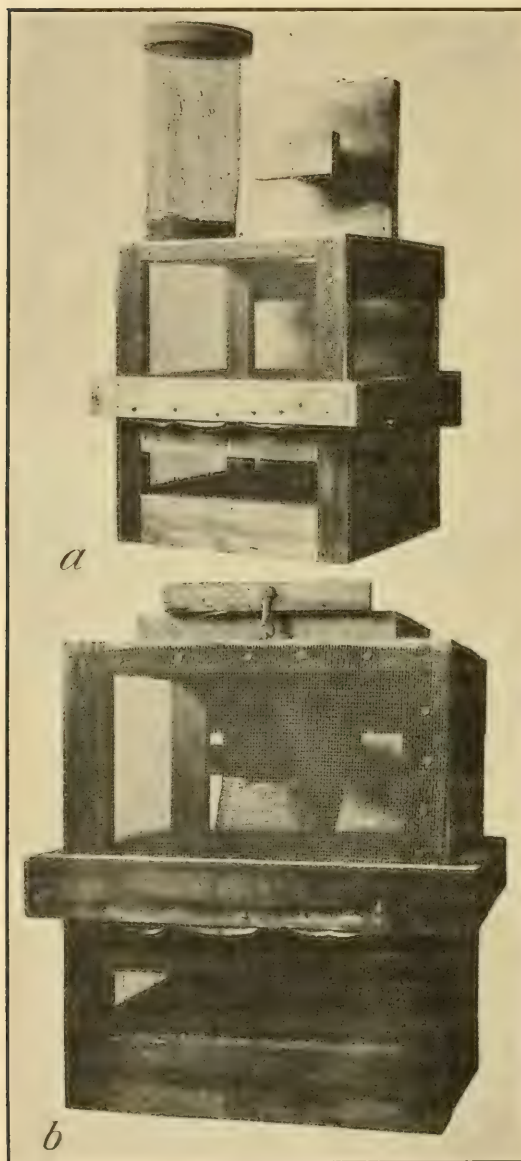


FIG. 20.—Assembling cage: a, Showing inner cage removed; b, cage ready for use. (Original.)

site sex. This trap was examined every three or four days until the middle of July, and then at less frequent intervals, but no males were caught. On August 11 the trap was removed.

Only negative results were secured from these experiments. It is probable that the tests should have been started earlier in June.

COPULATION.

After emerging from hibernation and feeding for a few days the beetles copulate, and egg laying is begun by the females. It is necessary for them to be mated with the males several times during the season, or a large percentage of infertile eggs will be laid. The record of a pair of beetles which were kept in a jar for the third summer is interesting as it gives data on the frequency of copulation of this species. The jar was examined once or twice a day when feeding records or other notes were being made. The pair was found *in coitu* June 27, 29, 30, July 8, 9, 10, 14, 15, 17, 18, 19, 20, and 26. They must have copulated at other times, because fertile eggs were laid on the date of the first copulation noted. The female deposited 274 fertile eggs during the summer. Old beetles show a greater desire to reproduce than young specimens.

In several cases females have been observed to copulate late in the summer, and no eggs were deposited thereafter. In each of these instances when the females were isolated in the spring without a male no fertile eggs were deposited until after a male was added and copulation took place. This indicates that the females can not be impregnated in the fall and lay fertile eggs the following season without further mating.

REPRODUCTION.

The highest number of eggs laid in a single season by a female was 653. The next highest number recorded is 514. These records are far above the average, as is shown in the following table:

TABLE XIV.—Average number of eggs laid by females of *Calosoma sycophanta* during 1908-1910.

Year.	Females ovipositing.	Females not ovipositing.	Total females.	Number of eggs.	Average for females ovipositing.	Average for all females.
1908.....	20	4	24	1,662	83	69
1909.....	52	23	75	8,115	156	108
1910.....	72	26	98	8,720	121	89

The data for 1909 and 1910 are probably the most valuable, as a larger number of specimens was under observation and fewer experiments had to be conducted with material taken direct from European shipments.

It will be noted that nearly one-third of the females did not deposit eggs, and it should be stated that most of these were young beetles.

The data secured from observations made in field colonies indicate that in many of these where beetle larvæ were liberated it has been possible to find excellent reproduction the next season. It is probable that under natural conditions the average number of eggs laid by all female beetles in the field, regardless of age, will be about 100.

Young beetles do not lay as many eggs the first season as those beetles that are a year older; in fact it appears that a certain proportion of the young females does not oviposit at all the first season.

Table XV gives the results of a series of experiments carried on during the summer of 1910. It shows the difference in the egg-laying habits between the young and the old beetles and indicates the relation between active oviposition and food consumption.

TABLE XV.—*Difference in the egg-laying habits between young and old beetles of Calosoma sycophanta and relation between active oviposition and food consumption, 1910.*

No.	Caterpillars eaten.	Larvæ produced.	No.	Caterpillars eaten.	Larvæ produced.
Young beetles:			Old beetles:		
4804.....	241	61	4808.....	305	191
4805.....	174	0	4809.....	289	44
4806.....	346	31	4810.....	290	317
4807.....	95	0	4811.....	328	97
Average.....	214	23	Average.....	303	162

It will be noted that the old *Calosoma* beetles ate more gipsy-moth caterpillars and laid many more eggs than the young female beetles, 50 per cent of which did not reproduce. The following year these beetles will oviposit freely, as has been repeatedly shown in the previous work.

In order to ascertain whether any difference would result in breeding old males with young females and vice versa, 4 pairs of beetles were tested and the results are given in the following table:

TABLE XVI.—*Results of breeding Calosoma sycophanta: (1) Old males and young females; and (2) young males and old females.*

Pair No.	Caterpillars eaten.	Larvæ produced.	Pair No.	Caterpillars eaten.	Larvæ produced.
Old males, young females:			Young males, old females:		
4812.....	216	0	4814.....	461	155
4813.....	188	0	4815.....	230	(¹)

¹ Eggs laid, but did not hatch.

The results shown in Table XVI should not be considered as conclusive owing to the small numbers of beetles used. It has occasionally been observed that young females reproduce when placed in jars with old males, and that the old females when kept in captivity with young males sometimes fail to do so.



ASSEMBLING CAGE FOR CALOSOMA BEETLES IN PINE TREE.

Arrow indicates position. (Original.)

It is evident, however, that greater reproduction takes place with old female beetles than with young ones, whether they are attended by young males or old males.

Some curious results of rearing experiments are given in Tables XVII and XVIII, which were prepared to show the length of life of adults of this species. Apparently it is the habit of these beetles to oviposit sparingly the first summer and freely during the second season. If conditions are very favorable the first year, a considerable number of eggs may be laid, while if they are unfavorable oviposition is postponed to the second or third summer as the case may be. It sometimes happens that eggs are laid the first and third summers, but not during the second; at any rate each female will lay about the same number of eggs, but the time when they are deposited varies greatly.

The data secured from field colonies bear out these facts. Two-thirds of the larval colonies have shown some reproduction the year following the planting, but in most cases the rate was very small, indicating that only a small proportion of the females laid eggs. By comparing the number of molted larval skins found in an adult colony in Wellesley, Mass., in 1908, and those secured in the larval colonies the year following their planting, it appears that the adult colony of old beetles reproduced thirteen times as rapidly as did the larval colonies during the year following their liberation. This may be explained in part by the greater tendency of the young beetles to disperse owing to scarcity of food or other natural causes, but it is evident that they reproduce much more slowly. The jar records indicate (see Table XV) that the old beetles multiply seven times as fast as young ones and an average in the field of 10 to 1 in favor of the old beetles would probably be about right.

POLYGAMY.

It has often been observed that females mate with the males several times during the summer and it is probable that this is necessary in order to insure the fertility of all the eggs.

Nearly every year several jars have been kept under observation where a single male was confined with 2 females and no cases have been noted where infertile eggs were deposited. In the summer of 1908 a record was kept of two jars, each containing a male and 3 female beetles. The insects fed voraciously and at the close of the season 306 eggs had been laid in one jar and 618 eggs in the other one, all of which hatched.

The average for each female in the first jar was 102 eggs and in the second 206 eggs, both of which are above the normal.

Although it is not known positively that each female in these jars laid eggs, it is probable that this was the case, owing to the large

number deposited, and if this supposition be true it indicates that a vigorous male beetle can successfully fertilize three females during the season and possibly more.

THE EFFECT ON EGG DEPOSITION OF REMOVING BEETLES FROM HIBERNATION.

In March and April, 1908, cages containing several pairs of beetles were removed and brought to the laboratory and kept in a heated room. These beetles began laying eggs slightly earlier than those that emerged from hibernation normally, and most of them finished ovipositing by the 1st of July. The number laid was far below the average that is usually deposited by normal beetles and many of the specimens died earlier in the summer than is usually the case.

EFFECT OF COLD STORAGE ON EGG DEPOSITION.

Several pairs of beetles were kept in cold storage during the winter of 1908-9. They were placed in the cold room soon after they developed from the pupæ and were removed March 16 and May 11, 1909. Very few of these laid eggs during the summer and most of them went into hibernation again the following winter. The number of larvæ produced the first year was far below the number secured from beetles of the same age that were allowed to emerge from hibernation at the normal time. In the case of old beetles the difference in the number of eggs deposited was not noticeable unless the beetles were kept in the cold room much longer than they would remain in hibernation under natural conditions.

RELATION OF SIZE OF BEETLES TO REPRODUCTION.

Among the specimens imported there is always considerable variation in size, and this is also true, possibly to a greater extent, with the specimens reared.

In order to determine whether differences in size had any special effect on the number of eggs deposited, measurements were made of a large number of the breeders during the summer of 1909.

Both sexes were measured, and in order to secure some standard to show the average size of each sex, four measurements were taken as follows:

- (1) Length from anterior edge of thorax to tip of elytra.
- (2) Length of elytra.
- (3) Width of elytra at humeral angles.
- (4) Length (ventral) of abdomen from between posterior coxal cavities to tip.

These measurements were added together and divided by 4 to get the average.

The egg records of 26 females are given herewith, the beetles being rated as large or small, those having average measurements that ranged above the general average being placed in the former class, and those below in the latter.

	Number.	Eggs laid.	Average of each.
Large females.....	15	3,848	256.5
Small females.....	11	1,846	168

This indicates that more eggs are normally developed by large females than by small ones.

It was desirable to determine, however, if the size of the males had any relation to the number of eggs produced, for if this were true the reliability of the data above given might be open to question.

Accordingly, typical data were secured from 9 males and 9 females which had been mated according to size, and are as follows:

	Eggs deposited.	Total.	Average per female.
Large male and large female.....	{ 496 208 }	704	352
Small male and large female.....	{ 200 342 }	542	271
Small male and small female.....	{ 189 175 }	364	182
Large male and small female.....	{ 134 207 85 }	426	142

This indicates conclusively that the size of the males is not an important factor relative to the number of eggs that the females will produce, and although there is quite a wide variation in the number of eggs laid by either large or small females, it demonstrates that large females will lay more eggs even when mated with a small male.

SEXES OF BEETLES REARED.

In order to determine the proportion of the different sexes of *C. syncophanta* reared from eggs laid, a careful record was kept of the sexes of the beetles that emerged in the spring of 1909 and 1910.

Of 71 beetles that were secured 39 were males and 32 were females (1909).

Of 512 beetles that were secured 261 were males and 251 were females (1910).

This indicates that under laboratory conditions practically the same number of each sex is reared.

EXPERIMENTS IN CROSSBREEDING CALOSOMA SYCOPHANTA AND C. SCRUTATOR.

During the summer of 1910, Mr. Collins conducted several experiments to determine whether these two species would interbreed. The beetles are of nearly the same size and it seemed worth while to determine whether this would occur in the field.

June 20, 1910, one male *C. sycophanta*, received from Europe in 1909, was placed in a jar with a female *C. scrutator* which was collected in Washington, D. C., in 1909, and hibernated here the following winter. The male emerged from hibernation June 1 and the female June 5. June 21, 8.30 a. m., Mr. Culver noted that the pair had been attempting copulation for the last half hour. At 8.40 a. m. the male succeeded in his attempt at copulation and remained *in coitu* until 8.43. June 22, 2.48 p. m., Mr. Culver again observed the pair in copulation, and watched them for 7 minutes before they parted. June 23, 1 small egg was found, and on June 25 several eggs were noted in the jar. July 12, none of the eggs had hatched. Jar cleaned out. July 25, the male *sycophanta* was removed from the jar, and a male *scrutator* added instead. July 29, female *scrutator* died. No eggs were laid after the male *scrutator* was added.

Another experiment was conducted as follows: June 16, 1910, a female *sycophanta* emerged from hibernation. The cage was dug up on June 23, but no male was found. The pair were pupæ in the fall of 1908 and the female did not reproduce in 1909. June 23, a male *scrutator* was added which was collected at Onset, Mass., August 3, 1909, and brought to the laboratory. This male was kept in a jar with one female which produced 22 larvæ that year. Infertile eggs were seen in the jar containing the female *sycophanta* on the date the male was added, but the latter paid no attention to the female. June 27, infertile eggs in jar; jar changed. June 28, infertile eggs in jar; jar not changed. June 29, infertile eggs in jar; jar changed. June 30, 2 p. m., the male attempted copulation with female *sycophanta* three times but was unsuccessful, although the latter stood quietly and attempted to facilitate the operation as much as possible. July 1, 2, 3, 4, and 8, eggs on surface; jar changed. July 9, male *scrutator* died. Male *sycophanta* added, copulation took place immediately, and on July 14 larvæ hatched from the eggs deposited in the jar.

In the above experiments with the two species, copulation was attempted and unions effected apparently with difficulty, but all of the eggs were infertile.

HABITS OF FLIGHT.

Few notes have been secured on the flying ability of this species. In the colonies the beetles have been frequently seen running about or climbing the trees, and they often drop from the branches to the ground without making any effort to fly.

Specimens confined in cages or jars have been observed to vibrate the wings rapidly. This is usually done soon after the beetles emerge from hibernation or toward evening.

A large cage of the native species, *C. scrutator*, was kept under observation one evening in June, and after twilight the beetles flew about the cage freely. This habit is well developed in this species, as the beetles are frequently taken at electric lights at night, in localities where they are abundant.

Apparently *sycophanta* must have the ability to fly, or the dispersion of the species in the field could not have been so rapid as is shown later in this report.¹

ATTRACTION OF THE ADULTS TO LIGHT.

As has been already noted, *C. scrutator* is frequently captured at electric lights. This does not often happen in New England, as the species is comparatively rare, but at Washington, D. C., and farther south, specimens can be commonly secured at arc lights during May and June.

Calosoma frigidum has this habit to some extent, as 2 males were captured at light traps at Reading, Mass., June 22, 1910.

Several observations have been made at electric arc lights located near colonies of *C. sycophanta*, but thus far no evidence has been secured which indicates that the beetles are subject to this attraction. Lights near a strong field colony at Oak Island, Revere, Mass., have been under observation when time permitted. No reports have been received from any of the field men that the beetles have been found at lights.

DROWNING EXPERIMENTS WITH BEETLES.

March 17, 1910, cages containing frozen earth were dug up, and 2 male beetles were removed from their cavities and put in a jar of water. At 11 a. m. the jar was placed in the laboratory ice chest and kept at a temperature of 39 degrees F. Some pieces of cloth and two small blocks of wood were put in the jar with the intention of keeping the beetles submerged, but at 5.58 p. m., when an examination was made, both beetles were found swimming about in the water. They were again submerged by placing a quantity of blotting paper inside of the jar, but on the following morning they had succeeded in making their way to the surface. A wooden float was then constructed which was placed in the jar in such a manner as to keep the insects under water. They were kept in this position 4 days, although every 12 hours they were taken out and examined

¹ During the last few days of May and the first part of June, 1911, both sexes of *sycophanta* were observed to fly freely in the field. This was shortly after emergence from hibernation and the beetles probably do not fly freely later in the season.

to see if they showed signs of life. At the end of this period, as they were apparently dead, they were removed, but in less than an hour they revived sufficiently to begin feeding on cutworms.

This experiment shows that beetles of this species can live for at least 4 days and probably longer, if submerged in water a few degrees above the freezing point.

March 17, 1910, several small wire cages, used for feeding larvæ, each of which contained a newly formed beetle, were dug up and submerged in a tub of water to see if the insects would survive this treatment. There were several inches of frost on the top of each cage, and the temperature of the water was about 39° F. March 18, at 8 a. m., 1 female had emerged and was clinging to the wire just above the water. An examination of the earth in this cage showed that the hibernation cavity was about 6 inches deep and as soon as it thawed out the insect made its way to the surface of the water.

Another cage was examined after it had been submerged 24 hours and a living beetle was found 3½ inches below the surface of the earth. The cage was replaced and removed later in the day and it was found that the beetle had worked its way to a point a half inch below the surface of the earth. It appeared dead but on removal soon revived.

At the end of 48 hours another cage was examined, and a live beetle found 3½ inches below the surface of the earth. This cage was replaced and on the following morning after it had been submerged for 2½ days the beetle was found on the surface of the water.

The last cage was opened at the end of 4 days, and an active female was found in the earth which was now very compact. The beetle was replaced in the mud and the cage submerged, but at 3.10 p. m. came to the surface of the water after having remained beneath it 4 days and 2 hours.

These experiments indicate that this species is able to withstand excessive amounts of moisture and that in the spring when lowlands are flooded the majority of the insects will survive, apparently without serious inconvenience.

On March 21 a female *Calosoma* beetle that had been submerged for 4 days and 2 hours was placed in a tub of water and floated about on the surface. It seemed desirable to ascertain how long the insect would remain alive and float when the water was maintained at about 39° F., and also whether it was able to make any progress in swimming. During the first hour and fifteen minutes the insect swam a distance of 22 inches. It rested on the water very easily, less than one-half of the body being submerged. The legs were moved continually, but its progress was very slow. This beetle remained in the tub of water 15 days and at the end of that period was removed for dead. In a few hours it revived and began feeding, and was used later in the summer in rearing experiments. This shows that in the

spring beetles of this species might survive several days if they should fall into ponds, and that they would probably float with the currents and might be distributed quite a long distance in this way, especially if they fell into streams or rivers.

LENGTH OF LIFE OF BEETLES.

Unlike most species of insects, such beetles of the genus *Calosoma* as there has been an opportunity to study are, as a rule, able to survive two winters and carry on active warfare against caterpillar life during two summers.

With species whose length of life extends over such a long period it is difficult to secure normal data if they are closely confined, and although the laboratory experiments show that *Calosoma sycophanta* usually hibernates two winters and sometimes more, it is probable that under normal field conditions even greater length of life could be reasonably expected. An abundant food supply naturally stimulates the activities and reproductive capacity of the species, and where such conditions prevail, the insects exhaust themselves more rapidly, and the length of life of the adult is therefore somewhat curtailed. Such evidence as is at hand seems to show that if for any reason the food supply is scanty the majority of the beetles are able to survive, although their activities and rate of reproduction are materially decreased.

This bears out the observations which have been made at different times on native species of *Calosoma* which have been found very abundant during local caterpillar outbreaks, although previously they were considered somewhat rare.

The tables which follow give a summary of the data secured on the length of life of adults fed in captivity at the laboratory. Specimens received from Europe enter into this computation to some extent, but of course it is impossible to determine with any degree of accuracy the length of life of such insects, as their previous history is unknown.

A record is given of the length of life of seven examples, 3 males and 4 females. These, with several others, pupated in the fall of 1907, but the others died, chiefly because unsuitable hibernation quarters were furnished during the first winter.

Of the 4 females noted above, all of which were supplied with males during the summer of 1908 and 1909, 1 fed during the summer of 1908, laid no eggs, and died in hibernation during the winter of 1908-9; 2 fed during the summers of 1908 and 1909, laid eggs the latter summer, and died August 10 and 26, 1909. The remaining female fed during the summers of 1908, 1909, and 1910, laid eggs the first and third summers, hibernated three winters, and died August 1, 1910. Of the 3 males, all of which were placed in jars with

females each summer, 1 fed during the summer of 1908 and died in hibernation during the winter, while the other 2 fed in 1908 and 1909 and died in hibernation cages during the winter of 1909-10.

To summarize, 1 male and 1 female lived one summer and died in hibernation; 2 females died at the end of the second summer; 2 males lived two summers and died in hibernation the third winter; and 1 female lived three summers and hibernated three winters.

The record of a female received from Europe in July, 1907, is of interest as it shows what may happen in nature if the conditions are favorable. This female was kept in a jar with a male after receipt, but laid no eggs and went into hibernation in the fall. During the following summer she was isolated in a jar containing earth and supplied with food. The beetle survived hibernation and many infertile eggs were deposited during the winter of 1908-9. A male was supplied during the summer of 1909, during which time 106 fertile eggs were deposited, and the female died July 20.

From the time of receipt until the date of death 2 years and 11 months elapsed, and this insect must have spent one winter in hibernation in Europe and perhaps more before being collected for shipment. In other words, the insect must have lived at least three summers and passed three winters in hibernation.

Among the beetles received from Europe in the summer of 1908 were 3 pairs from which were secured the following interesting records concerning length of life.

TABLE XVII.—*Longevity of 3 pairs of Calosoma sycophanta received from Europe during the summer of 1908.*

No.	Male.	Fe-male.	Eggs laid in—			Remarks.
			1908	1909	1910	
1513	1	1	0	0	238	Female died Aug. 8, 1910.
1592H	2	2	0	0	392	Females died July 25 and Aug. 13, 1910.

The females in this table failed to lay eggs until the second summer after receipt, and as soon as this was done they died. The length of life in each case was at least 3 full years. The imported males did not live so long, but their age at the time of receipt was unknown.

The table which follows gives data on the length of life of beetles which were reared in the summer of 1908. Each experiment was closed as soon as the female died, and in case the male died another specimen of the same age was added; hence more males than females are accounted for in the table.

TABLE XVIII.—*Longevity of 10 pairs of Calosoma sycophanta reared during the summer of 1908.*

No.	Male.	Fe- male.	Eggs laid in—			Hibernation, 1910-11.	Remarks.
			1909	1910	1911		
1735	1	1	0	179	.....	Male entered Aug. 26, 1910, died.	Female died Aug. 16, 1910.
1736	1	1	0	18	26	Male and female entered July 28, 1910.	Male died in hibernation in 1909, replaced; beetles died Aug., 1911.
1743	1	1	38	0	53	Male and female entered July 26, 1910.	Female died July 31, 1911; male died Aug. 12, 1911.
1771	1	1	0	0	25	do.....	Female died July 6, 1911; male died July 31, 1911.
1775	1	1	0	0	142	do.....	Male died July 5, 1911; female died July 11, 1911.
2705	1	1	0	310	.....	.....	Female died Aug. 3, 1910; male died Sept. 2, 1910.
2728	1	1	0	345	.....	.....	Male died June 21, 1909, replaced; female died Aug. 14, 1910.
2729	.....	2	0	0	332	1 male and 2 females entered July 28, 1910; male died.	Two males added in 1909; one died July 8, 1910; one female died Aug., 1911. ²
12775	1	1	156	290	.....	.....	Female died July 10, 1910.

¹ Age of male in this experiment not recorded.² Second female deposited eggs August 12, 1911.

Of the females listed in the table, 3 lived two summers, 5 died at the end of the third summer, and one is still living and ovipositing (Aug. 12, 1911). None of them laid eggs more than two seasons and some of them only one.

Of 10 males 4 died at the end of the first year or during the hibernation period following it, 2 died the second summer, and 4 the third summer.

These experiments indicate that, on the average, there is little difference in the length of life of the males and females. The latter commonly live two summers, and if the full number of eggs has not been deposited at the end of that time they continue to live until this result is accomplished, provided a sufficient food supply is available.

RELATION OF CALOSOMA SYCOPHANTA TO NATIVE SPECIES OF THE SAME GENUS.

The native species most closely resembling *Calosoma sycophanta* are *C. scrutator* Fab. and *C. willcoxi* Lec.

C. scrutator is more common in the central and southern part of the United States, and occurs somewhat rarely in the latitude of Boston, Mass., and farther north. It is a larger species than *C. sycophanta*; the green elytra are margined with a purplish band, and the thorax has a shiny copper-colored margin on all sides. These color markings distinguish it from *C. sycophanta*.

C. willcoxi is also a southern species but is occasionally found in Massachusetts and might be mistaken for a small specimen of *C. sycophanta*. It differs, however, in having color markings on the thorax and elytra similar to *C. scrutator*.

NATURAL ENEMIES OF CALOSOMA SYCOPHANTA.

During the summer of 1906 the remains of several dead *Calosoma* beetles were found under conditions which would indicate that the insects had been killed by some predatory enemy. In fact, one report reached the laboratory that a hairy woodpecker had been observed feeding on *C. sycophanta*. The locality where this observation was made was visited by Messrs. Titus and Mosher, and wing covers and fragments of legs and bodies of the species were found under a pine tree. Nearby was a nest of young crows, and it is probable that they were responsible for the trouble.

It is a well-known fact that crows feed on various species of carabid beetles, and specimens of native *Calosoma* have been found in the crops of these birds by various investigators, so that it would not be strange if they destroyed some of the imported ones.

In the fall of 1909 a report was received that birds, presumably crows, were destroying the beetles, as a number of fragments of the latter had been found on the ground in woodland near North Saugus, Mass. No absolute evidence was secured to prove that this was the case.

During the summer of 1910 Mr. H. S. Barber observed that several crows seemed to be loitering about in a locality where the larvæ of *C. sycophanta* were common under burlaps. None of the birds was seen in the act of feeding but the persistence which they exhibited in frequenting the locality aroused the suspicion that their mission was not a friendly one.

During the summer of 1907 all the dead *Calosoma* beetles that arrived in the shipments were isolated to determine whether parasites of any kind would develop, and of 584 beetles which were treated in this way, not one showed evidence of parasitic attack and no parasites were secured.

In rearing *Calosoma* beetles it is always necessary to guard against the accumulation of dead or decaying material. If such matter is permitted to accumulate in the rearing jars, the earth soon becomes infested with mites, which later attack the larvæ, or even the adult beetles. Probably in nature these insect enemies of the beetles do them no harm, as the conditions are not favorable for the increase of the mites.

During the summer of 1908 several jars became badly infested with a species of mite which was determined by Mr. Nathan Banks, of this bureau, as *Tyroglyphus armipes* Bks. The beetles were treated with carbon bisulphid, a small amount being applied with a brush to the underside of the thorax and abdomen, where the mites attach themselves most frequently.

The beetles survived the treatment perfectly, and after it had been repeated once or twice all the mites were destroyed. Several beetles

were freed of the mites by repeatedly scraping them with a small knife and brushing them with a small stiff brush.

Larvæ are more seriously injured by mites, and if attacked to any great extent will die either before or after pupating. This happened in several instances, and shows the necessity of keeping the jars as clean as possible.

In the spring of 1910 several young *Calosoma* beetles emerged from hibernation cages but died in a few days. An examination showed that the insides of the bodies were badly decomposed, and a large number of nematode worms was present. These beetles had been reared from larvæ late in the summer of 1909, and some of the lot were fed on gipsy moth pupæ that had been kept in cold storage and when removed were partially decomposed.

There was a considerable number of these pupæ in the cages late in the summer, and whether the nematode worms are able to feed upon them is not known. The death of the beetles may have been due to entirely different causes, and it is doubtful, judging from our experience, whether these insects are seriously injured by nematodes under field conditions.

A larva of *Curabus monilis* Fab. which was attacked, apparently, by the same trouble was sent to the Bureau of Plant Industry for determination, and on careful examination Dr. N. A. Cobb reported that two new species of nematode worms were present, viz, *Rhabdites calosomitidis* and *R. diplopunctata*. He is inclined to believe that these worms were introduced from Europe with the beetles, and that they may be injurious. Inasmuch as the specimen attacked was one that was reared from eggs deposited at the laboratory, the chance of the parasite having been introduced from Europe is somewhat remote.

COLONIZATION OF CALOSOMA SYCOPHANTA.

As has been previously stated, the first importations of this beetle that arrived in good condition reached Massachusetts in the spring of 1906, and from the number of specimens received it was possible for Mr. Titus and Mr. Mosher to liberate several colonies that spring. The method followed was to put out from 30 to 50 *Calosoma* beetles in a locality where gipsy moth caterpillars were plentiful, and during the season six colonies were liberated, and 389 beetles were used for this purpose. No attempt was made to determine the sexes of the beetles liberated, and the colonies were placed in the towns of Saugus, Malden, Winchester, Burlington, and Lynnfield, Mass.

In the early summer of 1907 the beetle importations were cared for by Mr. Mosher, and one large colony of 331 specimens was liberated early in July in a badly infested woodland directly north of the old parasite laboratory at North Saugus. Later in the season, after the beetle work had been taken up by the writer and Mr. Collins, a few

other colonies were released. A stock of beetles was added to one of the Lynnfield colonies that had been liberated the previous year, and new colonies were put out at North Woburn and Peabody. The first lot of beetles placed in the North Woburn colony was on July 31, which was late in the season for effective work, and on August 2 more beetles were added to the colony, making a total of 50 males and 50 females for this liberation. The colony in Peabody consisted of 25 males and 25 females, which were released August 28, 1907.

In 1908 less than 700 live beetles were received from Europe; hence only a small number of adult colonies could be liberated. Experiments were carried on, however, in rearing the larvæ of this species at the laboratory, and as a result of this work it was possible to liberate 2,300 larvæ in field colonies during the breeding season. The general plan of liberation was to place all the colonies in badly infested sections, where plenty of food was available, and where the insects would be disturbed as little as possible by hand methods of suppressing the gipsy moth. Several colonies were liberated on estates, and in some cases active hand suppression methods were carried on in order to prevent defoliation by the gipsy moth caterpillars. In a few instances the trees were heavily sprayed, and, although this was not in accord with the intention when the plantings were made, it gave an opportunity for securing data on the ability of the insects to survive in case they were handicapped by spraying or other control measures. A few small colonies were also liberated in York County, Me.

In 1909 the work was continued along the same lines, but a larger number of larvæ was planted in field colonies. It might be added that a single colony was liberated in the fall of 1909 at Sandwich, N. H., the reason for this being that while no gipsy moths had been found in this town, the maple, beech, and other forest trees were suffering from a severe outbreak of *Heterocampa guttivitta* Walk., and it was thought advisable to release a colony for the purpose of determining whether the insects would be able to survive at that northern latitude and do any considerable amount of good in reducing the number of these caterpillars.

In 1910 this work was carried on in much the same way, but an effort was made to liberate colonies in towns where none had been previously placed, providing, of course, that suitable localities which were badly infested could be secured for the purpose. The result of this policy has been that practically all the towns in Essex, Middlesex, and Suffolk Counties, and a few in Norfolk, and a single one in Plymouth County, Mass., have been supplied with one or more colonies of the Calosoma beetle.

In the first larval colonies from 75 to 150 or 200 specimens were released, but since that year it has been the practice to put out not less than 200 specimens in a colony, unless some of the adult beetles are

liberated at the same time, and in this case the number of larvæ liberated is often reduced one-half.

The method of liberating field colonies of *Calosoma* beetles has depended on whether adults or larvæ were to be planted. When adults were used, they were taken to the area selected and scattered about among the badly infested trees.

More care was required in distributing larval colonies as it was necessary to pack the larvæ separately so that they would not injure each other before they were turned loose.

In 1909 the larvæ were placed separately in glass tubes, both ends of which were plugged with cotton. Before inserting the last plug, a

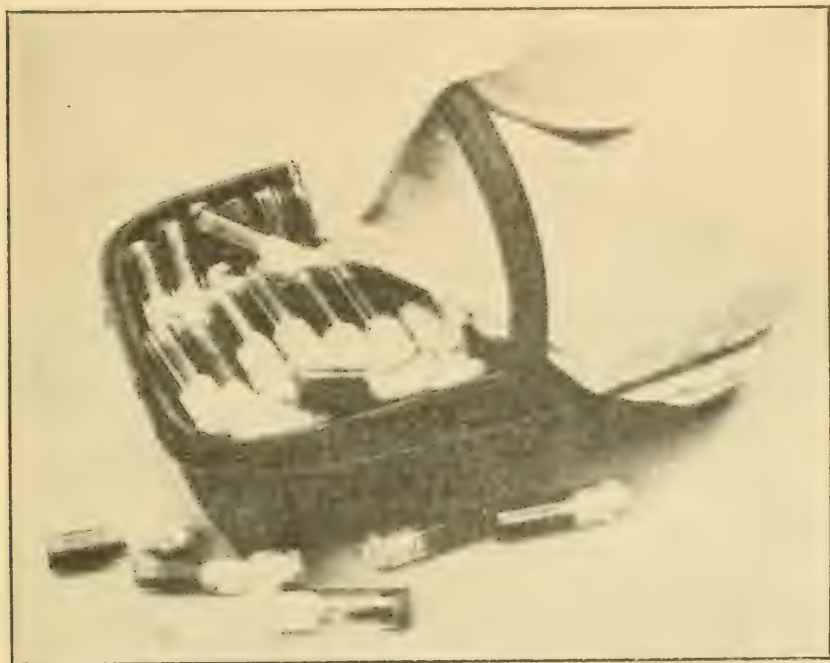


FIG. 21.—Two hundred tubes, each containing a larva of *Calosoma sycophanta*, ready for colonization. (Original.)

small amount of earth and sometimes a caterpillar or pupa was added with the beetle larva. These tubes were packed in a basket and taken to the place where the colony was to be liberated. (See fig. 21.) On arrival the contents were dumped at the base of infested trees and the tubes returned for refilling. Frequently the tubes became broken in handling and transit, and occasionally some of the larvæ made their way through the cotton plugs and escaped.

In 1910, a better device was used (fig. 22), which consisted of several units of wood in which was bored a double row of 10 holes, so that each block would accommodate 20 larvæ. The bottom of the block

was covered with fine-mesh copper wire to provide air, while on the top a sliding cover was arranged so that the holes could be closed as they were filled. Ten of these units were strapped together and were convenient to carry, and the colony (200 larvæ) which they contained could be liberated very rapidly by withdrawing the cover, inverting the unit, and giving it a sharp rap to shake out the insects.

Table XIX shows the number of living beetles imported and the number of beetles and larvæ colonized since the work began.

TABLE XIX.—*Number of living Calosoma sycophanta imported: and number of beetles and larvæ of Calosoma sycophanta colonized.*

Year.	Re- ceived.	Col- onized from importa- tions.	Reared and col- onized.	
			Adults.	Larvæ.
1906.....	693	389		
1907.....	967	578		
1908.....	675	430		2,300
1909.....	405	250		6,100
1910.....	1,305	1,064	452	6,350
Total.....	4,045	2,711	452	14,780

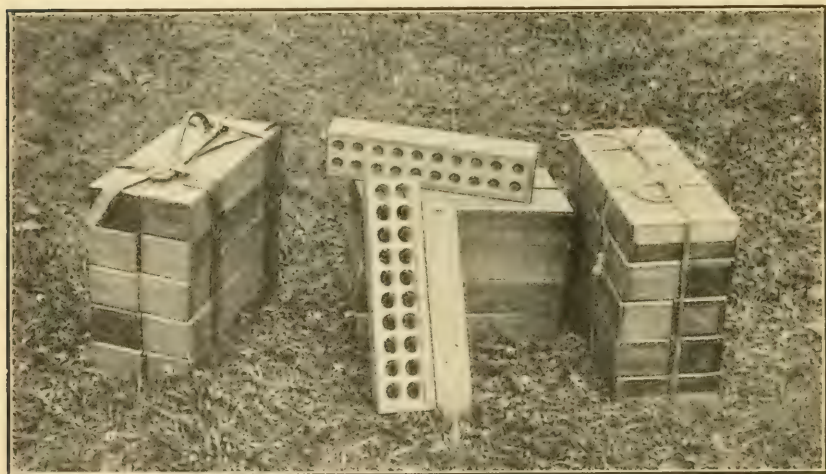


FIG. 22.—Three "sets," each containing 10 units, each unit holding 20 *Calosoma* larvæ in separate cells, so that each set contains 200 *Calosoma* larvæ or enough for a colony. (Original.)

During 1906 and 1907 the number of *Calosoma* beetles liberated was comparatively small and the following two years only a moderate number was colonized. It should be borne in mind that the present condition as regards the abundance and dispersion of this species in the field is due to the colonies liberated during the first two or three years rather than to those which have been planted since that time. Attention should be called to the fact that nearly as many beetles

were liberated during the summer of 1910 as had been released in all the previous years. This does not hold true in regard to the number of larvæ liberated.

Two years or more will be required before any accurate figures on increase in the colonies planted in 1910, or spread from them, can reasonably be expected. The information already given concerning the reproduction of new and old beetles bears directly on the conditions which exist in field colonies. If the beetles liberated in 1906 and 1907 reproduced at the normal rate, the progeny from these colonies should show far greater increase and dispersion than the beetles more recently liberated, and that this is the case will be brought out in the following pages. On the other hand, colonies consisting of larvæ, or beetles reared from larvæ, can not be expected to show any great increase for the first year or so, because young beetles ordinarily oviposit sparingly.

Owing to the fact that *Calosoma sycophanta* has been able to survive for a number of years under field conditions and that reproduction and dispersion have been going on at a satisfactory rate, as determined by observations made during the past four summers, it has been considered inadvisable to make further importations of this species, for the reason that if it is necessary to liberate more colonies aside from those that can be supplied from the material now being held at the laboratory, it should be possible to collect sufficient quantities in the field for the purpose.

METHODS OF SECURING DATA FROM FIELD COLONIES.

Since the work began it has been of the utmost importance to determine actual conditions in the field and to find out whether each introduced species was surviving and reproducing. During 1907 numerous visits were made to the colonies which had been liberated, but little of importance was found until about the middle of July, when Mr. L. S. Winchester, who had been employed for a few weeks to take up this particular work, found *Calosoma* beetle larvæ under the burlaps on trees where a colony had been planted in Burlington, Mass. This, of course, showed that the beetles had successfully hibernated during the winter and reproduced, and was a very encouraging sign. Later in the month several larvæ were found in the Saugus (Mass.) colony and a single larva was found in one of the colonies at Lynnfield, Mass., so that at the end of the season it was known definitely that three of the six colonies liberated in 1906 were well established in the field.

During the examination of the colony liberated by Mr. Mosher at North Saugus, Mass., in July, 1907, it was discovered, contrary to expectations, that the larvæ of this species climb the trees and feed upon the caterpillars and pupæ of the gipsy moth found on the trunks.

It also became apparent that many of the larvæ passed through the molting process on the trunks of trees, under burlaps, or among masses of caterpillars or pupæ of the gipsy moth. Later observations showed that this was a quite constant habit and in the years which followed it was made use of repeatedly as a means for determining the dispersion of this insect.

In 1908 plans were made to follow up the colonies more closely than had been done the previous year, and as the larvæ of this species had showed an inclination to secrete themselves under burlap bands where caterpillars were more or less abundant, it seemed advisable to burlap a number of trees in the center of each colony, so that conditions could be easily determined by occasional examinations of the burlaps during the summer. The plan was adopted of burlapping from 50 to 100 trees in each colony. The field work in these colonies was carried on by Mr. John V. Schaffner, jr., and Mr. F. V. Learoyd, and during the summer beetles or larvæ were found in all of the colonies except the one planted at Winchester. As it seemed desirable to continue this work after the larvæ had descended into the ground to pupate, and as very accurate results can be secured by searching for molted skins on the tree trunks, several weeks were devoted to this work. About the middle of July Mr. Learoyd was detailed to other work and Mr. Emory A. Proctor took up the field work in his place. As a result of these examinations it was also possible to trace the dispersion of the species in a limited way.

In 1909 the field examinations were carried on in the same manner by Messrs. Schaffner and Proctor, and late in the summer they were assisted by several other men employed at the laboratory. The results of the early summer inspection showed that the beetles existed in all of the colonies released in 1906, with the exception of one at Winchester. Of the total number of colonies placed in the field, 75 per cent were found to be reproducing. The results of the late summer inspection—that is, where the distribution of a species was determined by the presence of molted skins on the trees—is shown on the accompanying map (Pl. IX). This indicated a very encouraging increase and spread of the insect. The method of carrying on this work was to examine areas immediately outside of the beetle colonies which were badly infested with the gipsy moth, and if the molted skins were found, more territory was scouted until the outside limit of spread was reached.

During 1910 this work was continued, the same men having charge of the investigations in the field colonies. At the close of the work 80 per cent of all the colonies planted showed reproduction and much gratification was felt. Molted skins were found near the colony planted in Winchester in 1906, which indicates in all probability that some of the insects in that colony reproduced. The results of the

late summer scouting, in which work it was necessary to employ several assistants in order to cover the extensive territory which was examined, indicated that the beetles had spread over a much larger area than had been anticipated, and this is shown on the above-mentioned map (Pl. IX). In order to give an idea of the reproduction and dispersion under actual field conditions, a somewhat detailed account will be given of two colonies, namely, Saugus and Wellesley, Mass.

RECORD OF TWO FIELD COLONIES OF CALOSOMA BEETLES.

In July, 1907, Mr. Mosher liberated 331 beetles as soon as they were received from Europe in badly infested woodland near the old parasite laboratory at North Saugus, Mass. Larvæ of *syncophanta* were found later in the month and during the following year they were quite abundant. As there were plenty of gipsy moth caterpillars and pupæ for them to feed upon, it seemed desirable to determine the extent of spread and the amount of increase of the *Calosoma* beetles during the summer of 1908. In order to do this the woodland was examined thoroughly in August, and counts made of all the molted skins found. All the trees were climbed, and the rough bark, which was likely to harbor molted skins, was inspected, as were the masses of gipsy moth pupæ and the burlaps. Ninety-three first-stage and 294 second-stage molted skins were found in an area of about six acres, which seemed to represent the limit of spread of the species. That this was not the limit of spread, however, was definitely shown the next summer when larvæ and molted skins were found at intervals for more than half a mile in every direction.

In the fall of 1910 the colony was examined in the same manner as in 1908, and in the territory inspected the latter year 733 first-stage and 848 second-stage molted skins were found. This indicates that there had been an increase of the beetles in the center of the colony as well as a general dispersion of the species. A small block of trees adjoining this area was examined and molted skins were found in about the same relative numbers. A record of the dispersion from this colony could not be secured, because in 1909 it had merged with other colonies planted a mile or more distant.

In order to check up this data a careful scout was made, in the fall of 1908, of a colony at Wellesley Farms, Wellesley, Mass. The beetles that were placed in this colony, 105 males and 110 females, were received from Europe late in June, 1908, and were liberated July 1 of that year. The timber growth, which was chiefly oak, with trees of from 4 to 10 inches in diameter, had been burlapped, and two men were employed to destroy the gipsy moth caterpillars, as the infestation was bad. The beetles were liberated in two spots about 300 yards apart. The scouting in this colony consisted in

examining the burlaps and the trees as high up as a man could reach, as well as inspecting some of the stones or other material on the ground where the molted skins were likely to be found. Over an area of about 5 acres, 292 first-stage and 465 second-stage molted skins were found.

The following year no special inspection was made of the colony, but a general examination of the territory showed that the beetles had spread over about 2 square miles, chiefly to the westward.

In August, 1910, another careful examination was made similar to that of 1908, and in the same area that was examined the latter year 1,229 first-stage and 1,851 second-stage molted skins were found. The area over which the species had dispersed had also increased, so that evidences of the beetles were found over an area of 11.37 square miles. This colony was liberated in a region far away from other colonies, so that the spread did not come from other sources. A colony of larvæ was liberated in 1909 in Wayland and Weston, Mass., which area is now included, but it is improbable that these plantings spread to any great extent.

It is interesting to note the amount of handwork that was done in the colony. Although the trees had never been sprayed, the egg clusters had been treated each year with creosote. In the center of the colony the burlaps had not been turned, but in the remainder of the woodland they had been turned twice a week during the caterpillar season and the trees have never been defoliated.

COLONIES OF CALOSOMA LIBERATED IN MASSACHUSETTS.

The statement which follows gives a list of the towns and cities in which colonies of *Calosoma sycophanta* have been liberated, the number released, and a summary of the data which have been collected concerning the condition of the beetle colonies. This is given somewhat in detail, so that it may be of value to owners of property or residents in the several sections concerned.

Acton.—In West Acton, about $2\frac{1}{2}$ miles from the railroad station, 200 larvæ of *Calosoma sycophanta* were liberated on July 15, 1910. The gipsy moth infestation in this town was not serious at that time, and the *Calosoma* beetles were placed in a woodland colony where the gipsy moth infestation was such that the beetles would secure enough food to develop and reproduce the next season.

Amesbury.—*Calosoma* larvæ to the number of 200 were liberated in the woodland off Haverhill Street, in Amesbury, on July 11, 1910. The gipsy moth caterpillars were present in sufficient numbers to furnish food for the development of these larvæ.

Andover.—At this point 50 male and 50 female *Calosoma* beetles that had just emerged from hibernation cages at the laboratory were released on June 4, 1910, in badly infested woodland off Rattlesnake Road. The colony was examined July 14, 1910, but no *Calosoma* beetles were found. Gipsy moth caterpillars and pupæ were very scarce, owing to the fact that the infestation was so bad earlier in the season that most of those in the center of the colony died from starvation or disease.

Arlington.—On July 13, 1910, 200 beetle larvæ were liberated in woodland off Appleton Street. The condition of infestation by the gipsy moth in this section was favorable for the survival of the colony.

Bedford.—On June 9, 1910, 50 male and 50 female *Calosoma* beetles that emerged from rearing cages at the laboratory were released in the woodland on Page Road, near the Lexington town line. Gipsy moth caterpillars were common, and a liberal food supply for the beetles was assured.

Beverly.—On July 17, 1909, 200 *Calosoma* larvæ were liberated in woodland, which had been partially stripped by the gipsy moth caterpillars, off Essex Avenue. Most of the gipsy moth larvæ were full grown at the time the planting was made, and some pupæ were present on the trees. This colony was examined July 18, 1910, and several beetle larvæ and molted skins were found on the trees. On August 29, this colony was scouted by Mr. Proctor, who reported that molted skins of the beetle larvæ were found on trees to a distance of 500 yards from the center of the colony, and, as he states that the number of egg-clusters present indicated that there would be plenty of food for the *Calosoma* larvæ the following year, it is probable that this colony will develop and spread rapidly.

Billerica.—On May 27, 1910, 50 male and 50 female beetles were liberated in badly infested woodland near Ranlett's Park, South Billerica. These beetles were reared at the laboratory and had just emerged from hibernation cages. The gipsy moth infestation was very serious in this section, although at this time the caterpillars were rather small. July 29 the locality where the beetles were released was scouted by Mr. Schaffner, but no molted skins of the *Calosoma* larvæ were found. Many of the gipsy moth caterpillars died from disease earlier in the summer.

On June 24 a planting was made in woodland off Sprague Street, North Billerica. Fourteen males and 28 females, most of them being beetles that were reared at the laboratory, were placed in this colony. Plenty of gipsy moth caterpillars were present for food.

Boston.—No *Calosoma* beetles have been liberated within the city limits. One of the Brookline colonies has spread over the line into Boston in the Forest Hills district.

Boxford.—On June 27, 1910, 200 *Calosoma* larvæ were liberated in badly infested woodland about 1 mile north of the railroad station. Gipsy moth caterpillars were present in large numbers, and the locality was favorable for the development and increase of the beetles.

Braintree.—On July 19, 1909, 200 *Calosoma* larvæ were liberated in infested woodland on Liberty Street, South Braintree. Gipsy moth caterpillars and pupæ were abundant, and conditions were favorable for the increase of the beetles. June 9, 1910, the colony was examined by Mr. Schaffner, and a single *Calosoma* beetle was found. October 1, 1910, the colony was again scouted, and 1 first-stage molted skin was found. The burlaps in and around this planting had been turned periodically during the summer, and the gipsy moth larvæ and pupæ had been crushed, which of course served to reduce the beetles' food supply. While this was being done, it is probable that the molted skins of the beetle, which are ordinarily found under the burlap, may have been brushed to the ground, so that it was impossible to determine to what extent the beetles in the colony had reproduced.

Brookline.—Several colonies were planted in Brookline in the summer of 1908, and in 1909 another colony was added.

On July 4, 1908, 100 beetle larvæ were liberated in badly infested woodland off Hammond Street. Another colony, containing 81 male and 64 female beetles, was liberated in infested woodland off Newton Street, and on July 8, 100 beetle larvæ were placed in badly infested woodland off South Street. The colony liberated in 1909 consisted of 200 beetle larvæ, which were placed in badly infested woodland off Heath Street.

Repeated examinations were made during the summer of 1909 of the colonies liberated in 1908, and in each one, except the Hammond Street colony, a record of definite and satisfactory reproduction was secured. Considerable spraying was done along Hammond Street, and as this colony was liberated near the road it is very probable that the beetles migrated after they emerged from the ground. On August 31 several molted skins were found 500 yards from the center of the colony, which indicates that the beetles had migrated. Some of the trees in and around this colony were cut during the previous winter, and this may have had a tendency to induce the insects to migrate to a more secluded place.

In 1910 all the colonies liberated in 1908 were found in good condition, and the Heath Street colony also showed satisfactory reproduction and spread.

It might be added that the conditions in this town were not ideal for the colonization of *Calosoma sycophanta*, as a large amount of spraying had been done, which so reduced the number of gipsy moth caterpillars that it is probable that in such areas the beetles find it necessary to migrate after the effect of spraying becomes noticeable on the caterpillars.

During the time that has elapsed since these colonies have been planted, the ones on Newton Street and South Street have joined, spreading over the very considerable area indicated on the map. The Heath Street colony has also joined with a colony liberated in 1908 on Newton Street in the city of Newton, near the Brookline line. The reproduction in the last mentioned colony will be considered under the colonies in the city of Newton.

Burlington.—On May 8, 1906, Mr. Titus released 40 beetles in badly infested woodland about 1 mile west of Cummingsville, in the town of Burlington. This colony was visited several times during the year, but no beetles were found. On July 16, 1907, Mr. L. S. Winchester began scouting operations in this colony, and continued the work for about 10 days. On July 17 he found several *Calosoma* larvæ, and continued to observe specimens working under burlaps almost every day that he visited the colony, but no beetles were seen. A total of about 50 larvæ was found by him.

In 1908 several examinations of the colony were made, and on July 17 a dead beetle and 3 molted skins were found. The gipsy moth caterpillars were very scarce in the center of this colony, and undoubtedly migration from this locality had taken place.

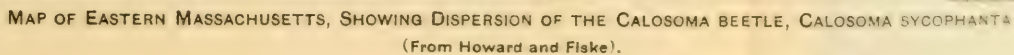
On June 21, 1909, 3 *Calosoma* beetles were found under burlaps, but no molted skins were discovered later in the season. On October 16 the woodland surrounding the colony was examined by Messrs. Schaffner and Proctor, and a few molted skins were found three-fourths of a mile from the colony. Later in the season more of the surrounding territory was examined, but no more evidence of the beetles was found.

In 1910 only a few molted skins were found, and these were a considerable distance from the center of the original colony. A large amount of territory was examined in this section of Burlington, without proving that the beetles were present. It might be said, however, that large areas of woodland in this region have been practically killed by the gipsy moth, and hence the infestation is not so bad as in some other sections where an abundance of foliage offers food for the caterpillars.

A colony that was liberated in North Woburn in 1907 had spread in 1909 to the northeastern part of Burlington, and in 1910 some beetles were found in this area.

Carlisle.—On June 22, 1910, 50 male and 50 female *Calosoma* beetles that had been received from Europe the previous day were liberated in badly infested woodland about 1 mile east of the Carlisle station.

Chelmsford.—On June 22, 1910, 50 male and 50 female beetles received from Europe the previous day were liberated in woodland where gipsy moth caterpillars were abundant. This colony was located near Billerica Road, about 1 mile from Chelmsford Center.



Cohasset.—On July 12, 1909, 200 *Calosoma* larvæ were released in badly infested woodland near the Jerusalem Road, and on July 27, 200 additional larvæ were liberated in woodland off Forest Avenue, about one-half mile from the colony previously mentioned. During the summer of 1910 the trees near where the first planting was made were badly defoliated. The colony was visited by Mr. Schaffner on July 1, but no beetles or larvæ were observed. Mr. Frank A. Bates, one of the agents employed by the State forester, informed me that he found several specimens of this beetle during that summer in this colony.

The colony off Forest Avenue was also visited by Mr. Schaffner on July 1. No beetles or larvæ were found, but the trees were not defoliated so badly as in the other colony. Examinations later in the season failed to reveal any traces of the beetle in this colony.

Concord.—On July 10, 1908, 25 male and 25 female beetles and 100 larvæ were released near Fairhaven Bay in infested woodland. Only a moderate amount of wooded area was infested, and most of the caterpillars had pupated at the time the liberation was made. June 28, 1909, a colony of 200 larvæ was liberated in the northwestern part of the town in badly infested woodland off Strawberry Hill Road. July 2, 1909, another colony of 200 larvæ was liberated near Walden Pond, in a moderately infested region. July 14, 1909, 200 larvæ were liberated in infested woodland off Sudbury Road.

During 1909 the Fairhaven colony was examined several times, and a few beetles and molted skins were found during the season.

Examinations made in 1910 indicate that the Fairhaven and Walden Pond colonies have survived, and that the beetles have spread a considerable distance from where the liberations were made. Only a few visits were made to the other two colonies, but no indications were found that the beetles had been working during the season.

Danvers.—On July 15, 1909, 300 *Calosoma* larvæ were liberated in woodland off Nichols Street, Danvers. The trees had been badly defoliated, and many of the caterpillars were dying from disease. A considerable number of gipsy moth pupæ was present. June 21, 1910, the colony was scouted by Mr. Proctor, and 2 male beetles were found. On September 17 another examination was made, and molted larval skins were found 200 yards from the center of the colony.

Dedham.—On July 9, 1910, 200 *Calosoma* larvæ were liberated in woodland off Sandy Valley Road.

Dover.—On July 2 1910, 200 *Calosoma* larvæ were liberated in woodland off Pleasant Street, Dover.

Dracut.—On June 24, 1910, 50 male and 50 female *Calosoma* beetles were liberated in badly infested woodland near Lakeview Park.

Essex.—On July 7, 1909, 149 *Calosoma* larvæ were liberated in infested woodland near Wood Drive, near Chebacco Lake. July 22, 1909, 200 *Calosoma* larvæ were liberated in woodland near a bad gipsy moth infestation off Conomo Drive. July 24, 1909, 200 larvæ were liberated in woodland off the Old Essex Road, near the town line of Manchester and Essex. All of these colonies were examined during the summer of 1910. On June 14, 2 beetles were found in the last-mentioned colony, but in the others no adults or larval skins were secured.

Framingham.—On July 16, 1910, 200 *Calosoma* larvæ were liberated near Framingham Junction, in infested woodland.

Georgetown.—On July 17, 1909, 200 *Calosoma* larvæ were liberated in woodland near Baldpate station. The infestation was moderate and conditions were favorable for a colony. June 16, 1910, the colony was examined, but no beetles found. The woodland had been sprayed, but many gipsy moth and brown-tail moth caterpillars were present. July 5 examination was made in the territory immediately outside of the colony and two *Calosoma* larvæ were found. On September 19 another examination

was made in and around the colony. A few molted skins were found under burlaps, and also some 100 yards east of the original planting.

Gloucester.—On June 23, 1908, 75 *Calosoma* larvæ were released in a moderately infested woodland area about 1 mile east of the West Gloucester station. July 14, 100 larvæ were liberated in an infested woodland area half a mile east of the West Gloucester station, and on July 30, 100 more larvæ were placed in the woods a short distance from the point where the last-mentioned liberation was made.

These colonies were examined in 1909. Nothing was found in the first colony, but in the second, beetle larvæ were observed on July 10 and 16, and later in the year a considerable number of molted skins was found.

July 20, 1909, 200 *Calosoma* larvæ were liberated in woodland off the State Road in Magnolia, and on July 22, 200 were placed in a badly infested wooded area near Haskell's Pond.

In 1910 all these colonies were examined during the summer, and in the early fall the surrounding region was carefully scouted for molted skins. No indications of *Calosoma* beetles were found in or around the colony liberated 1 mile east of West Gloucester station.

In the colony liberated near the West Gloucester station a few beetles were noted during that summer. Later in the season molted skins were found 1 mile south and 1 mile west of the center of the colony.

Molted skins were also found in the colonies liberated near the State Road at Magnolia and at Haskell's Pond, which indicated that these plantings had survived and the beetles were increasing.

Groveland.—On July 5, 1910, 200 *Calosoma* larvæ were liberated in an infested wooded area located on a hill near the center of the town of Groveland.

Hamilton.—On July 14, 1909, a colony containing 60 male and 44 female beetles and 100 larvæ was liberated in infested woodland off Farm Road. June 1, 1910, 1 male beetle was found in this colony. Later in the summer examination showed that several molted skins were present in the colony and a few were also found 100 yards distant.

Haverhill.—On July 5, 1910, 200 *Calosoma* larvæ were liberated in badly infested woodland about 1 mile north of the Groveland Bridge. On July 6, 200 larvæ were released in woodland in Bradford, near the electric car line from Haverhill to Andover.

Hopkinton.—On July 7, 1910, 50 male and 50 female *Calosoma* beetles received from Europe were liberated in infested woodland in Hopkinton.

Hudson.—On July 7, 1910, 50 male and 50 female *Calosoma* beetles received from Europe the previous day were liberated in infested woodland on Priest's Hill.

Hyde Park.—On July 19, 1910, 200 *Calosoma* larvæ were liberated in woodland near the corner of West and Austin Streets.

Ipswich.—On July 17, 1909, 200 *Calosoma* larvæ were released in woodland off Rowley Road. July 16, 1910, a male beetle was found in this colony. Gipsy moth caterpillars were very abundant, and the trees were being stripped of foliage. A later examination, made on September 20, 1910, revealed the presence of a considerable number of molted skins of the *Calosoma* larvæ in this colony.

Lawrence.—On July 18, 1910, 200 *Calosoma* larvæ were liberated in woodland off Beacon Street, South Lawrence.

Lexington.—On July 3, 1908, 100 *Calosoma* larvæ were liberated in woodland near the State Road in Lexington. The trees on the opposite side of the street had been entirely defoliated by the gipsy moth caterpillars, and many of those in the area where the liberation was made were badly stripped. Gipsy moth caterpillars were very scarce, but some moth pupæ were present on the trees where the *Calosoma* larvæ had been released. The colony was examined several times during the summer of 1909. No trace of *Calosoma* beetles or their larvæ could be found. Gipsy moth caterpillars were rather scarce. Several examinations were also made during the

summer of 1910 with the same result. Early in the season fire ran through the woods and burned over the area where the liberation had been made.

July 16, 1909, 200 *Calosoma* larvæ were liberated on the east side of the town, in woodland, off Paint Mine Road. The colony was examined several times during the summer of 1910, but no beetles were found. On October 4 several molted skins were found 100 yards outside of the planting, and also a large number of gipsy moth pupæ that had been eaten by the *Calosoma* larvæ.

Lincoln.—On July 18, 1908, 100 *Calosoma* larvæ were liberated in infested woodland about 1 mile northwest of the railroad station. The colony was examined several times during 1909, but few beetle larvæ were found. Gipsy moth caterpillars were very abundant in a part of this colony, and some of the trees were stripped, and this caused the owners to have a portion of the area sprayed. The colony was inspected several times in the summer of 1910 and a few *Calosoma* beetles were found. In the fall a careful examination showed that the beetles had spread about three-fourths of a mile north and one-half a mile east of the planting. A number of molted larval skins was found throughout this area.

Littleton.—On July 15, 1910, 200 *Calosoma* larvæ were liberated in woodland about one-fourth of a mile from the railroad station. Gipsy moth caterpillars were common, but none of the trees had been stripped.

Lowell.—On July 18, 1910, 200 *Calosoma* larvæ were liberated in woodland near the Lowell General Hospital.

Lynn.—No beetle colonies have been planted in this city, and up to and including the year 1909 no evidence of the presence of this insect could be found, although several days were spent in making careful examinations in various sections of the Lynn woods. It was believed that the insects would make their first appearance in that part of the city, owing to the fact that several colonies had been liberated in Saugus and Lynnfield. In the summer of 1910, in several localities which had been visited the previous summer, beetles and larvæ were found. Later in the summer examinations were conducted for molted skins, and in some parts of the Lynn woods they were found abundantly. Molted skins were also found throughout the northern part of the city and in the residential section nearest the woods.

Lynnfield.—On July 7, 1906, 100 specimens of *Calosoma sycophanta* and 20 specimens of *Calosoma inquisitor* were placed by Messrs. Titus and Mosher in woodland near Broadway. This colony was visited several times during the summer of 1907, but no beetles or larvæ were found. In 1908 examinations on July 2 and July 8 resulted in the discovery of several larvæ in the center of the colony. Several visits were made in 1909 and a considerable number of beetles and larvæ was found during June and early July. Later examinations were made and it was found that the *Calosoma* had spread over a large area in the eastern part of the town. It had also spread north and west so that this colony had fused with another, which will now be mentioned. June 20, 1906, Mr. Titus liberated 118 beetles in a pine grove which was nearly surrounded by hardwood growth. The trees were badly infested by gipsy moth caterpillars, and although several examinations were made later in the season no *Calosoma* beetles or larvæ were found. July 31, 1907, a single larva was found by Mr. Collins, and on the same date 50 pairs of beetles were liberated a short distance from the point where the previous planting had been made. Several examinations were made during the summer of 1908, and 2 live *Calosoma* beetles were found on July 23. In 1909 the *Calosoma* beetles were more numerous, and the examination of the surrounding territory showed that this colony had fused with the one in Lynnfield, already mentioned, and specimens were also found west of the colony in the town of Saugus. Subsequent scouting showed that two colonies in Saugus, which are treated under that town, had spread to such an extent that they had joined with the Lynnfield colonies. In 1910 examinations were made late in the season and traces of the beetles were found throughout the southern part of the town as well as in adjoining towns, which will be mentioned later.

Malden.—On May 8, 1906, Mr. Titus liberated 40 specimens of *Calosoma sycophanta* in badly infested woodland in Malden near the Saugus-Melrose line. During June, on visiting the colony, he was able to find 2 beetles. This colony was examined in 1907, but no trace of the *Calosoma* beetles or larvæ was found, and although several examinations were made the next summer nothing was found until July 16. On that date 6 full-grown *Calosoma* larvæ and about 25 molted skins were collected, some of them being taken 100 feet from the point where the original liberation was made. In 1909, *Calosoma* beetles and larvæ were abundant in this colony and in the fall a careful examination was made of the surrounding territory. It was found that the insect had spread over a section of Malden known as the Maplewood district and as far south as the Linden station. The beetles were also found over a considerable area in the southeastern part of Melrose, and in Saugus in the vicinity of Cliftondale. Some specimens were found in a section of Revere not far from the center of the colony, known as Franklin Park. In 1910 examinations showed that this colony had spread over practically the whole northern half of the city of Malden and into the adjoining towns and cities.

Manchester.—On July 27, 1909, 150 *Calosoma* larvæ were liberated in woodland on School Street, about one-half mile from the Essex town line. July 24, 200 *Calosoma* larvæ were liberated in a badly infested area off School Street, one-half mile farther north. Examinations of these colonies made in 1910 showed that in the latter a few beetles were present, but none was found in the first colony. Infestation by the gipsy moth was less severe than the previous year, as a large number of the moth caterpillars died from disease.

June 7, 1909, 39 male and 34 female *Calosoma* beetles were liberated off Crooked Lane, in Manchester. July 10, 300 beetle larvæ were liberated north of the area previously mentioned and not far from the Wenham line. Examinations made during the summer of 1910 failed to indicate the presence of the beetles near the point where the adult colony was liberated. Molted skins were found, however, near the larval colony; some were in the town of Manchester, others in Hamilton, and still more in Wenham. It is probable that some of these beetles spread from the colony located in the eastern part of Wenham, which will be mentioned later.

Marblehead.—On July 9, 1908, 100 larvæ of *sycophanta* were liberated in Marblehead about one-half mile east of the Forest River station. On July 15 of the same year 100 more larvæ were added to this same colony. Plenty of gipsy moth caterpillars were present and the *Calosoma* colony appeared to be in a flourishing condition when it was examined about a week later. During the summer of 1909 several visits were made to the colony, but no *Calosoma* beetles or larvæ were found. On June 30, 1910, the owner of the property said that he had seen two "green beetles" in the woodland earlier in the season, which were undoubtedly specimens of *Calosoma sycophanta*. Later in the summer molted skins were found near the Forest River station. Some beetles evidently had survived in this colony, but many had either migrated to other places or else conditions were not as favorable as might be wished for the rapid increase of the species.

Marshfield.—On June 30, 1910, 200 *Calosoma* larvæ were liberated in infested woodland near Marshfield Center.

Maynard.—On July 25, 1910, 200 *Calosoma* larvæ were liberated in badly infested woodland. Only a small number of gipsy moth caterpillars was present, but pupæ were more abundant.

Medfield.—On July 2, 1910, 50 male and 50 female *Calosoma* beetles were liberated in infested woodland in Rocky Woods.

Medford.—No colonies of *Calosoma* beetles have been liberated in this town, but during the summer of 1910 indications of the presence of the beetles have been found throughout the northern part of the city.

Melrose.—On June 25, 1909, 100 *Calosoma* larvæ were liberated in the northeastern part of the city not far from the Saugus-Wakefield line. June 30, 100 larvæ were added

to this colony. Practically every section of this city was examined in 1910 and beetles were found in small numbers throughout the entire area. It is probable that only a few of these came from this colony. Large numbers must have migrated from the colonies in Saugus and Malden. In the northeast section of the Melrose Highlands district the beetles were quite common in the woodland during the summer, and it was usually possible to find one or more of the beetles or larvæ at work if careful search was made.

Merrimac.—On July 11, 1910, 200 *Calosoma* larvæ were liberated north of Main Street, in Nichols Woods.

Methuen.—On July 6, 1910, 200 *Calosoma* larvæ were liberated in infested woodland in the eastern part of the town not far from the Haverhill line.

Middleton.—On June 23, 1910, 50 male and 50 female *Calosoma* beetles, which had been received from Europe two days previous, were liberated in badly infested woodland off East Street.

Milton-Quincy.—On July 6, 1909, 200 *Calosoma* larvæ were liberated in infested woodland near Shawmut Spring in Cunningham Park. This colony was visited only once during the summer of 1910, and no beetles or larvæ were found. At the time of the examination many of the gipsy moth caterpillars were dying as the result of spraying or from disease.

Natick-Weston.—On July 22, 1910, 200 *Calosoma* larvæ were liberated in badly infested woodland on South Avenue near the Natick-Weston line. There were many gipsy moth egg clusters and some moths present, but only a few gipsy moth pupæ and caterpillars.

Newbury.—On July 8, 1910, 42 male and 46 female *Calosoma* beetles, which had been received from Europe two days previous, were liberated in badly infested woodland near the Byfield station.

Newburyport.—July 26, 1910, 200 *Calosoma* larvæ were liberated in woodland near the West Newbury line. Some gipsy moth larvæ and pupæ were present, but a large number of the moths had laid their eggs.

Newton.—On July 4, 1908, 100 *Calosoma* larvæ were liberated in woodland off Newton Street, about one-fourth of a mile from the Brookline line. July 6, 1909, 1 female beetle and 9 larvæ were found on trees in the center of this colony, and later in the season when the surrounding territory was scouted a large number of gipsy moth pupæ was found that had been destroyed by the beetles. June 24, 1910, an examination was made and beetles found in the colony. The trees had already been sprayed. Late in July the territory between this colony and the one of Heath Street, Brookline, was visited and molted skins found in different localities between the places where the original liberations were made.

June 30, 1909, 200 beetle larvæ were liberated in woodland off Langley Road, Newton Center, and on July 13, 200 more larvæ were placed in the same woods about one-half mile from the original colony. The territory where these liberations were made was examined several times during the summer of 1910, and both beetles and larvæ were found.

North Andover.—On June 16, 1910, 50 male and 50 female beetles which emerged from hibernation at the laboratory were liberated in badly infested woodland off Osgood Street.

North Reading.—On July 6, 1910, 200 *Calosoma* larvæ were liberated in woodland about one-half mile from the State road.

Peabody.—On August 28, 1907, 25 male and 25 female *Calosoma* beetles that were received from Europe in August were liberated in wooded area which was badly infested. All the gipsy moth adults had emerged at this time, and but few caterpillars of any kind were present to serve as food for the *Calosoma* beetles. Several examinations were made during the summer of 1908, and on July 8 a full-grown larva of *C. sycophanta* was found under burlap. In 1909 several beetles were found in the

colony, although the gipsy moth infestation was rather light, and an examination of the surrounding territory in August failed to show any indications of the *Calosoma* beetles or their larvæ.

July 2, 1909, 100 *Calosoma* larvæ were liberated in woodland off Birch Street, West Peabody. Several examinations were made during the summer of 1910, and a few molted skins were found outside of the colony.

July 3, 1909, 200 *Calosoma* larvæ were liberated off West Street near the West Peabody station. In the summer of 1910 many larvæ and molted skins were found.

June 23, 1910, 50 male and 50 female *Calosoma* beetles just received from Europe were liberated in badly infested woodland near the Middleton Paper Mills.

Quincy. July 19, 1909, 200 beetle larvæ were liberated in a badly infested wooded area off South Street. Several examinations were made during the summer of 1910, and beetles and larvæ were found in abundance in and around where the colony was liberated.

Reading.—No colonies have been liberated in this town. Molted larval skins were found in the summer of 1910 in the southeastern and central parts of the town, having spread from the Saugus plantings.

Revere.—July 26, 1908, 100 *Calosoma* larvæ were liberated on Oak Island, and on July 27 100 additional larvæ were placed in this colony. These were liberated on the east side of the railroad track. On August 3 100 *Calosoma* larvæ were liberated on the extreme west edge of the wooded area. The colony has been visited each year, and beetles and larvæ have been found in moderate numbers.

Rowley.—On July 8, 1910, 200 *Calosoma* larvæ were liberated in infested woodland off the Newburyport Turnpike.

Rockport.—On July 13, 1910, 200 *Calosoma* larvæ were liberated in woodland in the rear of Manning Park.

Salem.—No colonies have been liberated in Salem, although a number of larvæ was released in Swampscott in 1908, not far from the Salem line. In 1910 an examination showed that the beetles had spread over the southern part of the city, the strip where they were found being about one-half mile in width.

Salisbury.—On July 11, 1910, 200 *Calosoma* larvæ were liberated in infested woodland in this town.

Saugus.—On May 6, 1906, Mr. Titus liberated 24 *Calosoma* beetles in woodland in North Saugus, and on June 26, 25 more were liberated in the same region. July, 1907, several larvæ were found in this colony, and in 1908 a few beetles were found.

July 3, 1907, Mr. Mosher liberated 228 *Calosoma* beetles in badly infested woodland directly north of the old gipsy moth laboratory at North Saugus, and on July 7, 103 more beetles were placed in this colony. *Calosoma* larvæ were found late in July, and in the summer of 1908 both beetles and larvæ were common in the center of the colony. This liberation was made about a mile from the one put out by Mr. Titus. In the summer of 1909 a careful inspection of territory showed that beetles were present in the area between the two colonies, and molted skins were found for a considerable distance surrounding each. The colony planted by Mr. Mosher had spread east and northward and fused with the Lynnfield colonies. It also had spread westward, as molted skins were found in woodland in the eastern part of the town of Wakefield. In 1910 the beetles were found in practically all parts of the town of Saugus.

Sherborn.—On July 2, 1910, 200 *Calosoma* larvæ were liberated in infested woodland off Main Street, Sherborn.

Stonham.—On June 22, 1908, 75 *Calosoma* larvæ were liberated in woodland off Franklin Street, Stonham. Examinations were made in this colony in 1909 and a few beetles were found. Several were also found in 1910. Later in the season a general inspection was made of the territory in Stonham where gipsy moth caterpillars had been very abundant. Molted skins were found in the eastern and southern parts of the town.

Stow.—On July 7, 1910, 48 male and 38 female *Calosoma* beetles were liberated in badly infested woodland.

Sudbury.—On July 25, 1910, 200 *Calosoma* larvæ were liberated in badly infested woodland in East Sudbury. On this date very few gipsy moth caterpillars or pupæ were present. Most of the moths had emerged and several had laid their eggs.

Swampscott.—On June 26, 1908, 75 *Calosoma* larvæ were liberated in infested woodland off Danvers Street. On June 30 100 more larvæ were added to this colony. Examinations were made in 1909, and a few beetles were found in the colony. In 1910 no beetles or larvæ were seen in the center of the colony, but in the area outside where gipsy moth caterpillars were at all abundant, molted skins were found.

July 1, 1908, 100 *Calosoma* larvæ were liberated on high land north of the Ocean House. On July 6, 100 more larvæ were added to the colony. Examination was made in 1909, but no beetles or larvæ were found. During the summer of 1910 several larvæ and molted skins were found from one-half mile to a mile distant from the colony.

Tecksbury.—On August 12, 1908, 100 *Calosoma* larvæ were liberated in woodland where gipsy moth caterpillars had been present earlier in the season. At this date all the moths had emerged and deposited their eggs. Brown-tail moth caterpillars were hatching and feeding on foliage of some of the deciduous trees. This colony was examined in 1909 and 1910, but no *Calosoma* beetles or larvæ were found. The colony was liberated principally as an experiment to determine whether it was possible for any of the beetle larvæ to survive and develop upon such a limited food supply.

July 2, 1910, 50 male and 50 female *Calosoma* beetles were liberated in badly infested woodland off Shawsheen Avenue. July 14, 1910, 200 beetle larvæ were liberated near Prospect Hill in infested woodland.

Topsfield.—On July 8, 1910, 180 beetle larvæ were liberated in badly infested woodland off High Street.

Wakefield.—No beetles have been liberated in this town. In 1909 it was found that a small area along the eastern border had been stocked with beetles from the Saugus colonies, and in 1910 the beetles were found in various localities in practically every part of the town visited.

Waltham.—On August 7, 1908, 100 *Calosoma* larvæ were liberated in wood and brush land off Lake Street. At this date no gipsy moth caterpillars were present. A few small brown-tail moth larvæ were feeding and occasionally a native caterpillar would be found. The *Calosoma* larvæ were nearly full grown, all having molted the second time. This colony was examined in 1909, and no beetles or larvæ were found during the summer, but on September 2 a single molted skin was found under burlap near the center of the colony. June 1, 1910, a beetle was found in the center of the colony, and in July several larvæ were noted. The territory surrounding was scouted in August and September and a considerable number of molted skins was found in Prospect Park, some of these at a distance of 2 miles south of the colony.

Wayland.—On July 12, 1909, 200 *Calosoma* larvæ were liberated in infested woodland off Poor Farm Road. The colony was examined in 1910 and a few beetles and larvæ were found near where the original planting was made. In September molted skins were found about 200 yards outside the planting.

Wellesley.—On June 27, 1908, 36 male and 37 female *Calosoma* beetles were liberated in infested woodland near Wellesley Farms station. July 2 69 males and 81 females, taken from a shipment received from Europe June 29, were liberated in this same colony. In the fall of 1908 an examination of the trees in this colony was made and a large number of molted skins was found on the trunks and underneath the burlaps. In 1909 and 1910 both beetles and larvæ were found in the center of the colony. In 1909 the territory in the northern part of Wellesley and extending into the southern part of Weston, about 2 miles in length and 1 mile in width, was inhabited by this species. In 1910 this region was kept under observation, and late in the season areas

outside were thoroughly examined. It was found that the general direction of distribution had been toward the north and west, and territory shaped like an onion embracing the northern part of the town of Wellesley and the southern part of the town of Weston, and extending to a point beyond the Weston railroad station, showed marked evidences of the presence of this insect.

Wenham.—On June 27, 1908, 6 male and 6 female *Calosoma* beetles and 75 larvæ were liberated in badly infested woodland off Cherry Street. In 1909 this colony was examined and beetles and larvæ were found. Late fall examinations showed that they had dispersed over a relatively small area. In 1910 the entire western end of the town was examined, and beetles were found over an area of about one-half square mile.

July 14, 1909, 43 male and 30 female *Calosoma* beetles and 100 of their larvæ were liberated off Grapevine Road. The territory was examined in 1910, and beetles and larvæ were found outside the colony. Beetles and larvæ were also found in the towns of Hamilton and Manchester at a distance of one-half mile or more from where this colony was liberated.

Westford.—On June 24, 1910, 100 *Calosoma* larvæ were liberated in woodland in the northern part of the town, and on June 28 100 more larvæ were added to the colony.

Weston.—On June 24, 1909, 100 *Calosoma* larvæ were liberated in woodland near the railroad station, and on June 26 100 more larvæ were added to the colony. Examinations were made several times during the summer of 1910. No *Calosoma* larvæ or molted skins were found in the colony, but several were secured in the area surrounding it. In the southern part of the town the beetles have become well established, having spread from the colony at Wellesley.

West Newbury.—On July 8, 1910, 200 *Calosoma* larvæ were liberated in woodland near the top of Pipe Stave Hill.

Westwood.—On July 9, 1910, 200 *Calosoma* larvæ were liberated in badly infested woodland.

Weymouth.—On July 19, 1909, 200 *Calosoma* larvæ were liberated in woodland off Commercial Street, Weymouth. The colony was visited several times in 1910, and on July 6 a beetle and 33 larvæ were found. Later in the season molted skins were found to be very abundant in this colony.

Wilmington.—On June 25, 1910, 100 *Calosoma* larvæ were liberated in woodland about one-half mile from the railroad station. June 30, 100 more larvæ were added to this colony. In 1910 beetles were found in the southern part of the town that had spread from a colony planted at North Woburn in 1907.

Winchester.—On May 8, 1906, Mr. Titus liberated 41 beetles in wood and brush land off High Street. During the winter most of the woodland was cut off, and although careful examinations were made during the summers of 1907, 1908, and 1909 no *Calosoma* beetles or larvæ were found in the center of the colony, but in 1910 molted skins were found about one half mile north of where the liberation was made.

Woburn.—On July 31, 1907, 23 male and 24 female beetles were liberated in the piece of woodland which had been partially stripped by gipsy moth caterpillars near North Woburn. On August 2, 25 pairs of beetles were added to this colony. Larvæ were found during the summer of 1908, and in 1909 a number of beetles was discovered in the colony and molted skins of the larvæ were found a mile distant. In 1910 the colony had spread over a much larger area, extending throughout the northern part of Woburn and into the towns of Wilmington and Burlington.

COLONIES OF CALOSOMA LIBERATED IN MAINE.

July 22, 1908, 100 *Calosoma* larvæ were shipped by express to Capt. E. E. Philbrook, Portland, Me. They were packed separately in glass tubes with earth and were liberated by him in Kittery and

Wells. Subsequent examinations have shown that the places selected for making liberations were not particularly suitable for the purpose, as the infestations were so scattering that a sufficient quantity of food was not available for the development of the larvæ.

Kittery.—On July 24, 1908, 15 *Calosoma* larvæ were liberated near Thaxters Station, under some oak trees upon which were some gipsy moth caterpillars. A wall near the base of these trees had been burned out before the planting was made. Later examinations during the year failed to reveal the presence of the *Calosoma* beetles and very few gipsy moths remained.

No beetles have been recovered from this colony.

July 25, 1908, 25 *Calosoma* larvæ were liberated on a large willow on the grounds of the Portsmouth Navy Yard. This tree was not badly infested, so there evidently was not sufficient food for the larvæ. No beetles have since been found in this planting.

July 31, 1908, 100 *Calosoma* larvæ were liberated on a small island of trees in the salt marsh. Gipsy moth caterpillars and pupæ were scarce at this time. Several examinations have been made since that time, but no *Calosoma* beetles have been recovered.

Wells.—On July 25, 1908, 20 *Calosoma* larvæ were liberated around fruit trees infested with the gipsy moth. Caterpillars were scarce on account of the careful handwork that was being done. No beetles have since been recovered. On examining the trees in the summer of 1910, it was not possible to find either the gipsy moth caterpillars or pupæ.

York.—On July 24, 1908, 30 *Calosoma* larvæ were liberated in woodland slightly infested with the gipsy moth. Although several examinations have since been made, no *Calosoma* beetles have been found.

COLONY OF CALOSOMA LIBERATED IN NEW HAMPSHIRE.¹

July 31, 1909, 100 *Calosoma* larvæ were liberated in woodland near the Sandwich-Tamworth line, which was being defoliated by *Heterocampa guttivitta*. The gipsy moth had not been found in this region, but it was desired to see whether the *Calosoma* beetles would feed on *Heterocampa* and survive the winter.

An examination was made August 24, 1910, but no *Calosoma* beetles were found. *Heterocampa* larvæ were very scarce throughout this section of the State.

ECONOMIC IMPORTANCE OF CALOSOMA SYCOPHANTA.

The preceding pages show conclusively that this beneficial species, *Calosoma sycophanta*, is firmly established in eastern Massachusetts. The data also show that although in most cases some traces of the insect's presence have been found the year following planting, it takes three years or more before they are sufficiently abundant to attract attention.

For this reason the beetles have not been found by many residents of the district infested with the gipsy moth. The question of the part which this insect is destined to play in controlling the gipsy

¹ Molted skins of *sycophanta* larvæ were found in August, 1910, at Plaistow, N. H. The adults must have migrated from some of the Massachusetts colonies.

moth is one which must be settled by future developments rather than by prophecy or pure speculation.

The feeding period of the beetle and its larvæ corresponds closely with that of the larval and pupal stages of the gipsy moth, and therefore there seems to be no good reason why it will not take prominent rank with the true parasites of this insect and assist and supplement their work.

Its ability to survive and reproduce in New England has been clearly demonstrated when it is stated that as a result of the planting of 13 adult and 14 larval colonies from 1906 to 1908, the presence of the beetle was found over an area of about $9\frac{1}{2}$ square miles in the summer of 1909. During that year 3 adult and 29 larval colonies were liberated and in the summer of 1910 the insects were found scattered over about $106\frac{1}{2}$ square miles in Massachusetts.¹ The aggregate rate of multiplication and dispersion increases with the age of the colonies. Future observations will show the precise value of this insect as an enemy of the gipsy moth.

¹ Examinations in the early summer of 1911 of the regions where liberations have been made indicate that the beetles have continued to increase and spread at a very satisfactory rate.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 102.

L. O. HOWARD, Entomologist and Chief of Bureau.

NATURAL CONTROL OF WHITE FLIES
IN FLORIDA.

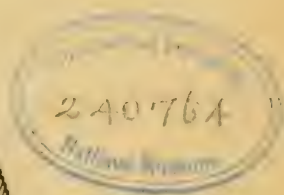
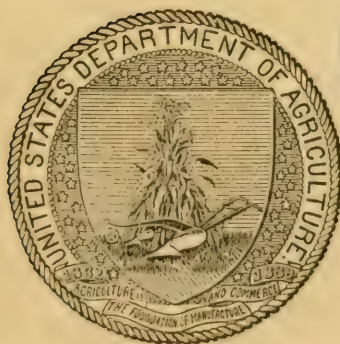
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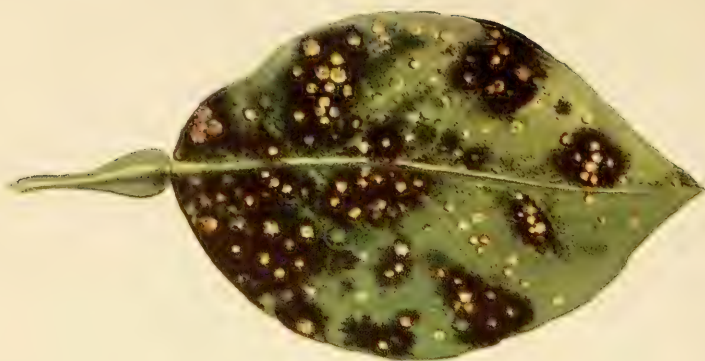
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FUNGUS ENEMIES OF WHITE FLIES.

Upper figure, the yellow fungus (*Aschersonia flavocitrina*); middle figure, the red fungus (*Aschersonia alcyrodis*); lower figure, the brown fungus (*Eggrita webberi*). Three-fourths natural size. (Original.)

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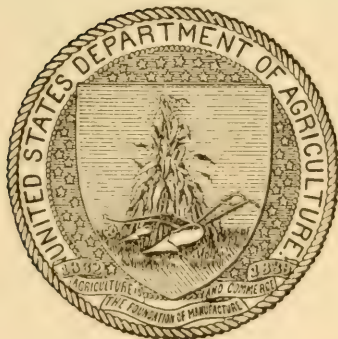
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CITRUS AND SUBTROPICAL FRUIT INSECT INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., November 3, 1911.

SIR: I have the honor to transmit herewith for publication as Bulletin 102 of the Bureau of Entomology a report on "Natural Control of White Flies in Florida," by Drs. A. W. Morrill and E. A. Back, both of whom were formerly employed as special field agents in this bureau.

The control of the citrus white flies in Florida by natural means, most important among which are the fungous diseases of these insects and natural insect enemies, is a subject of much importance to the Florida citrus grower. In connection with the investigation of the white fly in Florida a good deal of time has been devoted to this special subject, and the results are here summarized. This investigation has been under the general direction of Mr. C. L. Marlatt, assistant chief of this bureau, and has been carried out by the authors named with the assistance and cooperation of Mr. E. L. Worsham, now State entomologist of Georgia, and Mr. W. W. Yothers.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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NATURAL CONTROL OF WHITE FLIES IN FLORIDA.

INTRODUCTION.

The control of the citrus white fly (*Aleyrodes citri* R. & H.) by means of the natural enemies already established in Florida has long been a subject concerning which there have been many diverse opinions and insufficiently supported conclusions, but very little definite knowledge. Opportunities for extended investigations of the subject were first offered in 1906 when the work was taken up independently by the Bureau of Entomology—as one phase of the white-fly investigations begun in July of that year—and by the Florida Agricultural Experiment Station. While the field work conducted in the two investigations has been largely along somewhat parallel lines, the duplication of work in the case of such a difficult and important problem is of great advantage in advancing our knowledge upon which final conclusions must be based.

It is not feasible to present in this publication more than a small selection from the large amount of data which have been secured in connection with the investigations of natural control, but it has been the purpose here to present such data as are necessary properly to support important conclusions. The nature of the more important conclusions is such as to render unnecessary complete discussions of minor topics, which would be necessary under other circumstances.

The investigations of the parasitic fungi were conducted by the senior author during the season of 1906; by the senior author, by Mr. E. L. Worsham, now State entomologist of Georgia, and by the junior author during the season of 1907; by the junior author during 1908, and by the senior and junior authors jointly during 1909. Mr. W. W. Yothers has aided at various times in connection with field work and has furnished certain data, as hereinafter specifically credited, in connection with the "white-fringe fungus." Mr. Worsham has been specifically credited where his results have been utilized. Practically all of the experimental results included herein are based on the work of the seasons of 1908 and 1909.

Thanks are extended to Prof. P. H. Rolfs, Dr. E. W. Berger, and Prof. H. S. Fawcett, of the Florida Agricultural Experimental Station, for the many courtesies extended during these investigations. Acknowledgment is also made of assistance rendered by Mrs. Flora W. Patterson, mycologist of the Bureau of Plant Industry, to whom many specimens of fungi have been submitted for examination and for information. The colored plate is the work of Mr. J. F. Strauss, of the Bureau of Entomology.

PARASITIC AND PREDATORY ENEMIES OF WHITE FLIES.

So far as known, there is no true insect parasite of the citrus white fly (*Aleyrodes citri* R. & H.) or of the cloudy-winged white fly (*Aleyrodes nubifera* Berger) in this country. Dr. Howard, however, has recently recorded ¹ the finding at Lahore, India, by Mr. R. S. Woglum, of this bureau, of the exit holes of true parasites. In the examination of specimens of parasitized white flies, verified as *Aleyrodes citri* by Prof. A. L. Quaintance, Dr. Howard has found dead specimens of a minute aphelinine which he has described as a new species under the name of *Prospaltella lahorensis*.

During the course of these investigations, two species of *Prospaltella*—*P. aurantii* How., and *P. citrella* How.—and two species of *Encarsia*—*E. luteola* How., and *E. variegata* How.—have been quite thoroughly tested with abundant material as to their ability to parasitize the citrus white fly.²

In addition to the outdoor attempts at colonization in the event of successful parasitism, laboratory observations were made upon the behavior of many specimens of the first three species in the presence of larvæ and pupæ of the citrus white fly in all stages of development. Only one incident of especial interest was noted. One female specimen of *Prospaltella aurantii* showed a peculiar interest in a plump white-fly (*A. citri*) pupa, and in addition to carefully examining it she spent several minutes in attempting to force her ovipositor through the skin of the aleyrodid, apparently without success.

With the exception of *Encarsia variegata* How., the parasites mentioned have not been tested as to their ability to parasitize the cloudy-winged white fly. *Encarsia variegata* seems to confine its attentions entirely to *Paraleyrodes perseæ* even when the citrus white fly and the cloudy-winged white fly are present in greater abundance.

In case the Indian white-fly parasite (*Prospaltella lahorensis*) fails to become established in Florida or proves unable successfully to attack either of the two species of white fly under the conditions prevailing in the Gulf coast region, the work of testing all procurable aleyrodid parasites should be continued. Owing to the danger of introducing hyperparasites, suggested by Dr. Howard's studies³ of material reared from *Aleyrodes coronata* Quaintance, it appears advisable to conduct work of this kind in greenhouses far from citrus-growing regions.

¹ Journ. Econ. Ent., vol. 4, pp. 131-132, February, 1911.

² The first two species were reared from *Aleyrodes coronata* Quaintance, collected by Mr. E. M. Ehrhorn in California and sent to the Orlando Laboratory through Dr. Howard. The third species was reared from *Aleyrodes fernaldi* Morrill, collected at Amherst, Mass., and sent to the Orlando Laboratory by Dr. H. T. Fernald. The fourth species of parasite is of common occurrence in Florida, where it has an important economic rôle in holding in check a citrus-infesting white fly, *Paraleyrodes perseæ* Quaintance.

³ Proc. Ent. Soc. Wash., vol. 10, nos. 1-2, p. 65, 1908.

• Mr. Woglum has found two coccinellids in India at Saharampur which attack the citrus white fly,¹ which have been determined as *Verania cardoni* Weise and *Cryptognatha flavescens* Motsch. In Florida three ladybirds, *Chilocorus bivulnerus* Muls., *Cycloneda sanguinea* L., and a very small black species, *Scymnus punctatus* Melsh., have been observed to destroy white-fly eggs and larvæ, but have never been found to be effective in controlling the white fly to a noticeable degree. The same may be said of a capsid bug, which attacks adult white flies, and two or three species of lacewing flies or chrysopids. These latter might become of considerable importance were they not so subject to attack by several hymenopterous parasites which destroy the greater part of them in the pupal stage, and in addition a species which destroys their eggs. Several species of spiders are predaceous upon adult white flies; several species of ants destroy the larvæ, pupæ, and adults, and a species of thrips destroys the larvæ and pupæ. This last-mentioned insect, described by Dr. H. J. Franklin² as *Aleurodothrips fasciapennis*, has, according to the observations of the authors,³ proved more effective than any other of the native insect enemies of the citrus white fly.

The combined attacks of all of these natural enemies, however, have thus far proved of no noticeable benefit in reducing the white flies, with the exception of a few rare instances where the thrips referred to appeared to accomplish some good in supplementing other factors of natural control.

The testing of all procurable species of ladybirds as possible white-fly enemies would seem to offer the most hopeful field for future work with predatory enemies aside from the work of foreign exploration recently undertaken. There are comparatively few species of this beneficial group whose tastes are so well known that it would be safe to predict that they would not attack either the citrus white fly or the cloudy-winged white fly in the egg, the larval, or the pupal stage.

SNAILS THAT FEED ON SOOTY MOLD.

It was observed in 1903, by Mr. F. D. Waite, of Palmetto, Fla., that a snail⁴ was of considerable value in one grove in removing the sooty mold (*Meliola* sp.) from citrus leaves and fruit. Since then it has been found in many hammock groves in the State of Florida, more especially in Manatee and Lee counties. Without artificial protection in the attempt to encourage their multiplication these snails rarely reduce the sooty mold appreciably on more than a few trees at a time. When abundant, however, well-blackened trees may

¹ Journ. Econ. Ent., vol. 4, no. 1, p. 131, February, 1911.

² Ent. News, vol. 20, pp. 228-231, 1909; Proc. U. S. Nat. Mus., vol. 33, p. 727, 1905.

³ Ent. News, vol. 23, pp. 73-74, 1912.

⁴ Determined for Dr. E. H. Sellards by Dr. W. H. Dall as *Bulimulus dormani*.

be entirely cleansed of sooty mold, leaving the fruit rinds and upper surface of the leaves bright and glossy. Straw on the ground around the base of the trees and pieces of burlap hung in the crotches of the main branches protect the eggs of the snails to a certain extent, but birds and probably other natural enemies prevent their attaining a position of reliable economic importance. Live white flies in any stage are not eaten by the snails to any appreciable extent, the destruction of a few being entirely incidental. Strictly speaking, therefore, snails are not factors in the natural control of the white flies, but in their effects they may appropriately be mentioned in this connection. The species referred to above has been given the common name of "Manatee snail" by Dr. E. H. Sellards, who has published an account of its habits.¹ Additional notes have been published by Dr. Berger, who has also referred to another species of similar habits, the "Miami snail," introduced into Manatee County from Miami, Fla., by Prof. Rolfs.²

CLIMATIC CONDITIONS.

An examination of climatic records for points in California where both the citrus white fly and the cloudy-winged white fly have been temporarily established shows conclusively that these destructive insects are dangerous under any climatic conditions in the United States where citrus fruits are grown. The citrus white fly thrives on privets (*Ligustrum* spp.) and Cape jessamine (*Gardenia jasminoides*) out of doors in sections where winter temperatures are too severe for citrus trees. Freezing temperatures therefore have no effect in citrus-growing sections except through the shedding of the leaves of citrus. In proportion to the thoroughness with which this occurs both species of white flies are reduced in numbers, sometimes being entirely exterminated locally. In cool March weather heavy winds accompanied by beating rains have been observed to destroy practically all the adults of the first broods. During March and April there often occurs in Florida a rather high rate of mortality among the overwintered pupæ, which may be tentatively ascribed to weather conditions. Apparently associated with the mortality mentioned is the lower daily mean humidity and the greater daily range in humidity than occurs at other seasons of the year. Strong drying winds seem especially to characterize these periods of unusually high mortality. (Plate II, upper record.) According to the observations made, mortality among the overwintering pupæ during the first emergence period of the year ordinarily ranges from 19 to 38 per cent. In one instance, however, this mortality amounted to about 92 per cent, with a strikingly beneficial result in the grove where observed.

¹ Science, n. s., vol. 24, pp. 469-470, 1907; Fla. Agr. Exp. Sta., Press Bul. 59, pp. 1-4, Jan. 15, 1906.

² Bul. 88, Fla. Agr. Exp. Sta., p. 69, January, 1907; Rep. Fla. Agr. Exp. Sta. for fiscal year ending June 30, 1909, p. xliii.

UNEXPLAINED MORTALITY.

Early in the present investigations it became evident that mortality among larvæ and pupæ resulting from unrecognized causes was the most important element of natural control affecting the species of white flies herein considered. To this the authors have applied the term "unexplained mortality." This mortality has never been taken into consideration in previous publications, and in the past no little confusion has existed owing to the failure to distinguish between the benefits derived from it and those from fungous parasites, and attempts at artificial control by ineffective insecticides or other futile means.

White flies dying from unexplained causes ordinarily have the same characteristics as insects that have been killed by fumigation or by some sprays. After dying the insects turn light brown and in the course of several weeks generally become more or less whitened. The dead insect sometimes becomes infected with the saprophytic "white-fringe" fungus. There is very little unexplained mortality among overwintering pupæ, unless the mortality occurring during the period of emergence of the adults in the spring be properly classed as such, instead of being considered as due to climatic conditions.

In a previous publication¹ the senior author has recorded an instance where entire credit for the temporary freedom from white-fly injury was commonly given to fungous parasites when mortality from other sources was concerned to an unknown degree. The instance referred to was that in Manatee County, Fla., in the summer of 1906. Observations during the past two years have led the authors to consider that the unusual reduction in the numbers of the citrus white fly in Manatee County in 1906 was accomplished by the combination of two important factors—fungous diseases and unexplained mortality; also, that the former probably by themselves could not have produced the conditions which existed, while the latter unaided might have done so.

These two conclusions are based on the general studies of the effectiveness of fungous parasites, in the first case, and on a knowledge of the possible effectiveness of unexplained mortality in the second. The effectiveness of fungous parasites is discussed elsewhere. The possible effectiveness of unexplained mortality is shown by one of the most remarkable instances on record of the temporary checking of the citrus white fly and the cloudy-winged white fly by this natural-control influence, which occurred during the summer and fall of 1906. The effect was most noticeable in Orange County near Orlando, in a district where the senior author was quite generally conversant concerning the grove conditions.

¹ Bul. 76, Bur. Ent., U. S. Dept. Agr., pp. 64-65, 1908.

Occurring coincidently with one of the most unusual periods of drought ever recorded in Florida, the reduction of white flies throughout the city limits of Orlando and in the majority of the infested citrus groves in the vicinity was at first thought to be due to the weather conditions. An analysis of the available data concerning the weather conditions in different locations where the white flies have become successfully established indicates that with little doubt this idea was erroneous.

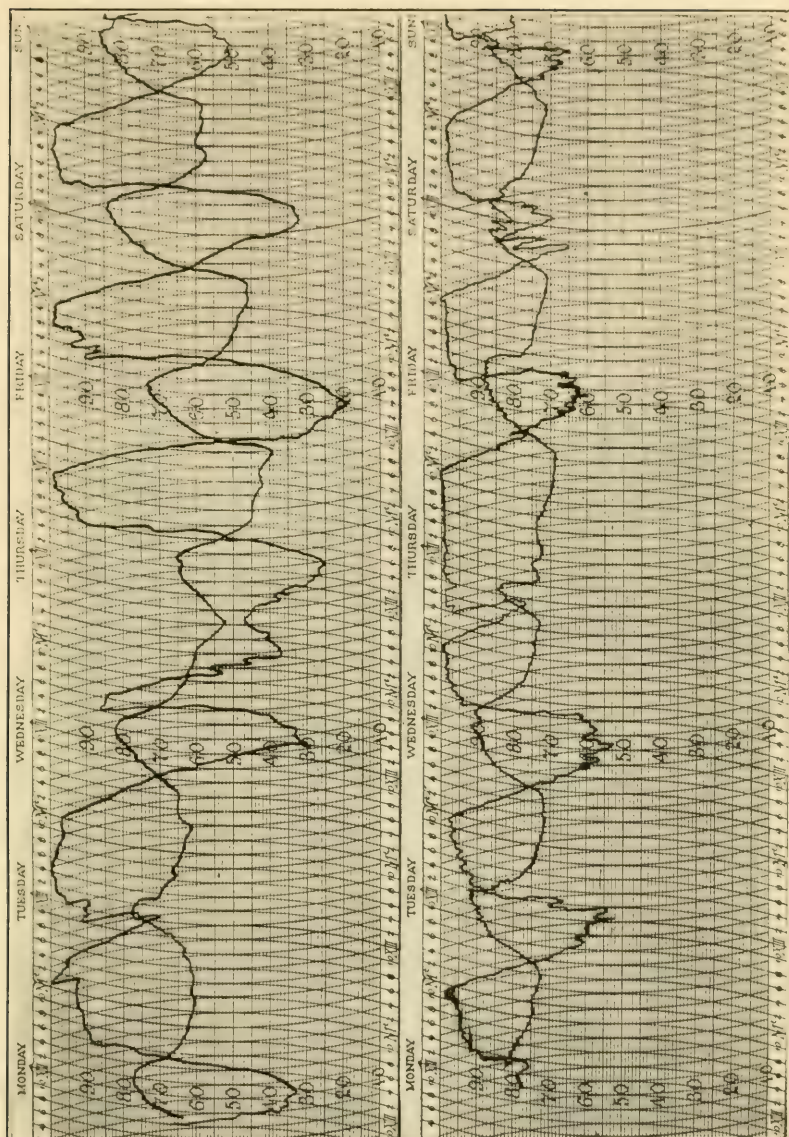
Fungous parasites were thought by some to have been responsible for the situation here considered. While such a conclusion might have been drawn in 1906 from observations in a few selected groves, the white-fly conditions in 1907 in these same groves offered positive proof that the fungous parasites exerted an insignificant, if appreciable, influence toward the general reduction in the numbers of white flies. The brown fungus appeared to be effective in one small grove of about 100 trees located near the center of the city of Orlando. Aside from this, no instance of effectiveness of fungous parasites in the locality referred to was known to the senior author, who is responsible for the observations. A comparison of the conditions during 1906 and 1907 in representative groves and in yards in and near Orlando will show the status of fungous parasites with relation to the situation. (See Table I.)

TABLE I.—*White-fly conditions in and near Orlando, Fla., during 1906 and 1907.*

Grove No.	Varieties.	White flies, 1906.	Parasitic fungi, 1906.	Foliage.	
				1906.	1907.
1	Mostly grapefruit; a few oranges and tangerines.	Both <i>A. citri</i> and <i>A. nubifera</i> in about equal numbers.	Traces of yellow; no red. The former abundant on a few trees.	Slightly blackened.	Clean.
2	Grapefruit, oranges, and tangerines.	do.....	Yellow and red considered together more abundant than elsewhere in locality.	Varying from slightly to moderately blackened.	About same as in 1906.
3	Mostly oranges; a few grapefruit and tangerines.	Mostly <i>A. citri</i> ; a few <i>A. nubifera</i> .	Red very abundant in one section. Traces of brown.	In general very black.	Clean.
4	Oranges entirely.....	All <i>A. citri</i> , so far as observed.	Traces of red.....	Slightly blackened.	Clean.
5	Oranges entirely.....	Mostly <i>A. citri</i> ; very few <i>A. nubifera</i> .	Absent, so far as observed.	Blackened.....	Clean.
6	Oranges, grapefruit, and tangerines.	do.....	Red abundant in certain places, traces in other places, and absent in others. Traces of brown.	Generally blackened.	Clean.

Grove No. 1 is that belonging to Capt. J. S. Jouett and is located near the north end of Orange Avenue in Orlando.

Grove No. 2 is that of Mr. C. B. Thornton and is located near Orange Avenue, a few hundred yards southeast of 'grove No. 1. The condition in this grove (No. 2) is especially significant, since, notwithstanding the comparative abundance of the parasitic fungi



HUMIDITY AND TEMPERATURE RECORDS MADE BY COMBINED HYGROGRAPH
AND THERMOGRAPH AT ORLANDO, FLA.

Left-hand record, illustrating unusual conditions which appear to be associated with high rate of spring mortality affecting overwintered pupæ of white flies; right-hand record, midsummer record during period of unusual fungous activity. (Original.)

in 1906, white flies were more abundant in 1907 in this grove than in any other grove or section in or near Orlando.

The white-fly laboratory was located in grove No. 3 during 1906 and 1907. This grove, the property of Hon. J. M. Cheney, is located immediately south of No. 2. The red *Aschersonia* was more abundant on a certain group of trees in this grove than on any other trees in the locality covered by these observations. The white flies were most abundant in this section of the grove in 1907, while in other sections, where only traces of the fungus occurred, the insects had become very scarce before September 1, 1906, and were least numerous in 1907.

Grove No. 4 is the "Wilcox Grove," located immediately south of Mr. Cheney's grove (No. 3). The foliage in this grove was only slightly blackened at the time it first came under the observation of the senior author in August, 1906, the insects even then being on the decline in point of numbers. In this grove the fly was so effectively reduced that it did not multiply to the point of slightly blackening the foliage until the fall of 1908.

Grove No. 5 was known as the "William Dennen Estate Grove" and is located about one-half mile south of the city limits, immediately south of the Atlantic Coast Line Railroad. This grove was so seriously injured in 1905 and looked so unpromising in the winter of 1905-6 that it was considered inadvisable by those in charge to go to the expense of fertilizing until some satisfactory method of control was discovered. In the spring of 1906, during an unfavorable period, the grove was sprayed twice, the adults being then on the wing. In this instance spraying was at first believed to be responsible for the cleaning up of the grove, but examination in several groves of the effectiveness of the applications made by the same spraying outfit, and the experience of the authors in their experimental work, eliminate beyond doubt the possibility that the two applications of sprays were responsible for the scarcity of white flies. Mr. E. H. Walker, chairman of the Orange County horticultural commission, who had general charge of the extensive spraying carried on in the Orlando district in 1906, agrees with the authors in considering that the spraying, whatever its effectiveness may have been by itself, could not have produced such striking results. The first trace of red fungus was found in this grove in the fall of 1908 by the senior author. By this time the white fly had increased to the extent of slightly blackening the foliage of a few trees. The greater effectiveness of the unexplained mortality in this grove (No. 5) as compared with the effectiveness of this factor throughout the city of Orlando was due to the absence of china-trees (*Melia azedarach*) and umbrella china-trees (*Melia azedarach umbraculifera*) in the immediate neighborhood. These trees, as explained in previous publications,¹ are

¹ Bul. 76, Bur. Ent., U. S. Dept. Agr., 1908 (see Chinaberry); Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911 (see China-tree).

important aids to the citrus white fly in regaining its normal abundance after it has been reduced by any cause.

Grove No. 6 in Table II represents the general condition of trees in yards in Orlando aside from the groves 1 to 5. The important point shown by this is that whether the parasitic fungi were present or absent, the general condition in 1907 was practically the same throughout the city.

The foregoing general observations led to a more detailed investigation of mortality from unexplained causes, and a large amount of data concerning the subject has accumulated. For the most part these data cover too great a range of conditions to be briefly summarized for this report. One series of observations, however, was made especially with a view to securing records under uniform conditions and sufficiently extensive to enable certain definite conclusions to be reached concerning this important subject. The data presented in Table II are based upon the examination of about 275,000 insects found on 1,155 leaves. All but No. 6 represent citrus groves in Orange County selected on account of the comparative abundance of fungous parasites, or because common reports placed a particularly high estimate on the effectiveness of the fungous parasites in them. In several cases it had been generally reported that the fungous parasites had brought the white fly into complete subjection. No. 6 includes a mixed lot of leaves from seven different points in the city of Orlando, representing town conditions. The first record was made by the senior author on October 19, 1908, and the others were made by the junior author in December, 1908. The leaves were 1908 growth, and mostly midsummer growth of that year. For convenience in the discussion the records in Table II are arranged in order of the percentage of unexplained mortality.

TABLE II.—*Study of causes of mortality of white flies near Orlando, Fla., in 1908.*

Grove No.	Number of leaves examined.	Total number white-fly forms counted.	Leaf averages.				Percentages of totals.						
			Killed by fungous parasites.	Unexplained mortality.	Emerged (pupa cases).	Alive.	Red Aschersonia.	Yellow Aschersonia.	Brown fungus.	Cinnamon fungus.	Total percentage killed by fungous parasites.	Unexplained mortality.	Surviving: Alive and matured. ¹
1	85	8,813	24.5	24.5	5.6	49.1	9.5	0.05	14.1	0.0	23.6	23.6	52.8
2	100	6,541	27.1	34.0	.7	3.6	.0	41.2	.0	.0	41.4	52.0	6.5
3	100	10,832	1.7	72.6	2.0	32.0	.0	1.6	.0	.0	1.6	67.0	31.4
4	100	13,257	19.2	89.9	3.4	20.0	4.0	10.4	.0	.1	14.5	67.8	17.6
5	100	22,922	29.6	157.2	6.5	35.9	.38	12.5	.0	.0	12.9	68.6	18.5
6	85	36,841	29.8	306	17.8	80.6	6.2	.06	.08	.6	6.9	70.5	22.6
7	100	11,944	16.4	91.8	1.9	9.3	.4	13.3	.0	.0	13.7	76.8	9.5
8	100	59,728	80.9	469.5	16.4	30.6	12.5	.05	.03	.9	13.5	78.7	7.7
9	100	28,242	43.9	228.5	1.7	8.4	5.8	1.6	7.9	.2	15.5	80.9	3.6
10	100	46,935	84.2	380.6	2.8	1.7	10.1	2.1	5.2	.5	17.9	81.1	.95
11	100	14,702	17.9	119.2	2.4	7.5	2.7	9.4	.0	.1	12.2	81.1	6.5
12	85	19,540	9.7	210.8	1.1	8.3	.7	2.1	.6	.9	4.2	91.7	4.1

¹ Represented on leaves examined by empty pupa cases.

An examination of the data in the last three columns of the above table shows a striking relationship between the unexplained mortality and the insects which survived. In the case of the fungous parasites, however, there seems to be no striking relationship of this kind. In order to make this point clear the six records (Nos. 1 to 6, inclusive) with the lowest percentages of unexplained mortality and the six records (Nos. 7 to 12, inclusive) with the highest percentages of unexplained mortality are here summarized and compared with a similar summary with regard to fungous parasitism rearranged from the same data:

Unexplained mortality:

6 lowest percentages averaging 58.2 per cent, 24.9 per cent survived.

6 highest percentages averaging 81.7 per cent, 5.4 per cent survived.

Fungous parasitism:

6 lowest percentages averaging 8.5 per cent, 15.1 per cent survived.

6 highest percentages averaging 21.1 per cent, 15.2 per cent survived.

It appears from the above summary that a difference of about 24 per cent in unexplained mortality in two groups of groves was associated with a difference of about 20 per cent in the insects which survived. On the other hand, a difference of about 13 per cent in the deaths due to fungous parasites was associated with no appreciable difference in the proportion of insects which survived.

In December, 1910, Mr. S. S. Crossman, at the suggestion of the junior author, made a series of records to correspond with 10 of the 12 included in Table IV. A summary of the 10 records for the two years is given in Table III.

TABLE III.—*Status of white flies in 10 groves at ends of seasons 1908 and 1909.*

Year.	Total number white fly forms examined on 1,000 leaves.	Leaf averages.			Percentages of totals.		
		Killed by fungus.	Unexplained mortality.	Alive and matured.	Per cent of fungous infection.	Per cent of unexplained mortality.	Per cent surviving; alive and matured.
1908.....	259,054	34.0	203.1	33.5	12.4	73.7	13.9
1909.....	107,191	16.3	76.5	14.5	15.4	71.0	13.7

In five groves a larger percentage of surviving insects was found in 1909 than in 1908, in four groves a smaller percentage of surviving was found in 1909 than in 1908, and in one grove there was no appreciable difference in this percentage, as shown by the two examinations. Unexplained mortality ranged from 23.6 to 91.7 per cent in 1908 and from 61.8 to 78.8 per cent in 1909. The following is a summary for 1910 based on arrangements of the data to show relation between unexplained mortality and fungous diseases to the number of insects surviving.

Unexplained mortality:

5 lowest percentages averaging 66.1 per cent, 15.7 per cent survived.

5 highest percentages averaging 76.1 per cent, 11.7 per cent survived.

Fungous parasitism:

5 lowest percentages averaging 10.2 per cent, 14.7 per cent survived.

5 highest percentages averaging 20.5 per cent, 12.6 per cent survived.

In the above summary the comparatively small difference between the five highest and five lowest records in each case makes the results less striking than are the results of the previous year. However, it is noteworthy that a difference of 10 per cent in unexplained mortality shows a corresponding difference of 4 per cent in the number surviving, while a difference of 10 per cent in the fungous parasitism shows a difference of 2.1 per cent in the number surviving.

A fair estimate of the results produced by either unexplained mortality or fungous diseases must include a consideration of the increased degree of benefit from each if it had been the only factor concerned with the mortality of the larvæ and pupæ on the leaves. This point has been discussed elsewhere as to fungous diseases. Assuming that, in the 10 groves considered in Table III, the 12.4 per cent recorded as infected by parasitic fungi in 1908 and the 15.4 per cent in 1909 were actually destroyed by the fungi,¹ a large part of those infected by fungi would have died from unexplained causes if the fungi had not been present. Eighty-eight of every one hundred larvæ and pupæ were not infected by fungi in 1908 and 85 of every 100 were not infected in 1909. Of these 84.1 per cent (73.7/87.6) and 83.8 per cent (71.0/84.7), respectively, died from unexplained causes. It must therefore be assumed that if no fungous parasites had been present 84 and 83.8 per cent of the 12.4 and 15.4 per cent recorded in Table III would have died from unexplained causes, giving a total efficacy for unexplained mortality of 84.1 per cent and 83.9 per cent, respectively, for the years 1908 and 1909. This efficacy, combined with the effects of fungous diseases and overcrowding, did not result in a condition of satisfactory control in the average grove in 1908, with an average of about 24 live pupæ per leaf, nor in 1909, with the average reduced to 11 live pupæ per leaf. In each year there was a satisfactory condition of control in two or three of the groves under observation or a promise of such a condition the following season. In the opinions of the authors the data here given, representing a small selection of the large amount of similar data at hand, covering all sections of the State of Florida, conclusively show that the fluctuations from year to year in the proportion of white flies dying from causes as yet unexplained are of first importance in the periodical "cleaning up" of infested citrus groves.

More attention should be given to a study of the cause or causes contributing to the unexplained mortality herein discussed. Attempts

¹As shown elsewhere, the brown fungus is known to infect dead as well as live insects.

to separate pathogenic bacteria from material sent to the Bureau of Animal Industry have not thus far been successful. There is certain evidence that some organism is directly concerned. As a rule unexplained mortality is greater in heavily infested groves than in lightly infested groves, although it is not dependent upon this point to a great degree after the insects have once become well established. The data in Table II, illustrating ordinary conditions in groves long infested, are here summarized:

Average number of forms per leaf:

6 lowest, averaging 112.7, 61.3 per cent unexplained mortality.

6 highest, averaging 368.3, 78.5 per cent unexplained mortality.

It should be noted that unexplained mortality was from 2.3 to 12.5 per cent greater in the case of record number 11, averaging 147 forms per leaf, than in the case of either record numbers 5, 6, or 8, averaging 229, 434, and 597 forms per leaf, respectively. Of the twelve records the one showing the highest unexplained mortality ranks seventh in point of average number of forms per leaf.

In newly infested groves or in groves where the white fly has been temporarily greatly reduced from any cause, unexplained mortality as a rule is comparatively low. Grove No. 1 in Table VI, that of Hon. J. M. Cheney, previously referred to as to its condition in 1906 and 1907, shows a condition which may follow the reduction of the white fly to a negligible quantity for a season. Table IV gives the results of the examination of white flies in six newly infested groves, no fungous diseases, so far as could be detected, being present in any case:

TABLE IV.—*Conditions with regard to unexplained mortality of white flies in newly-infested groves.*

Grove No.	When examined.	Number leaves examined.	Total number of forms counted.	Average number white fly forms per leaf.	Percentage of unexplained mortality.
1	Dec. 4, 1906.....	27	5,503	20.4	12.0
2	Sept. 13, 1907.....	100	150	1.5	15.3
3	Oct. 15, 1907.....	10	2,094	20.9	30.5
4	Aug. 16, 1908.....	100	1,222	12.2	24.2
5	Dec. 8, 1908.....	41	233	5.7	12.4
6	Dec. 2, 1909.....	25	12,801	51.2	10.9

Both species of white flies herein considered are affected by mortality from unexplained causes, but the effect on the cloudy-winged white fly (*Aleyrodes nubifera* Berger) seems to be more pronounced as a matter of control, since the absence of food plants other than citrus tends to prevent the rapid increase in infestation which results in the case of the citrus white fly when its useless food plants are neglected. In the foregoing records both species were present, the citrus white fly greatly predominating.

DROPPING FROM LEAVES.

Daily observations made on marked larvæ from date of settling to emergence of adults, in connection with life-history studies, proved that a small proportion of larvæ loses hold upon the leaves and drops, especially at molting periods. Of 231 marked larvæ, 20 (or 8.6 per cent) dropped before reaching maturity. This dropping occurred in nearly every case after the larvæ had passed several days in the plump condition preceding molting and were in no way pressed for room. While dropping is largely restricted to the earlier instars, one pupa has been known to drop after having shown developed eye-spots for nine days. Where infestation is excessive, dropping is more frequent than noted above, but is then due more directly to overcrowding, as shown under the following heading.

MORTALITY DUE TO OVERCROWDING.

The excessive overcrowding of leaves with eggs always results in the death of practically all the larvæ that hatch, as it either becomes a physical impossibility for them to find suitable places for attachment, or, because of the closeness of the eggs, such spaces as they do find are far too limited to permit development to the pupal stage.

TABLE V.—*Effect of overcrowding upon development of the citrus white fly.*

Leaf No.	Number of eggs deposited.	Number live larvæ.	Number live pupæ.	Number pupal cases.	Per cent alive.
1	13,882	0	2	0	0.01
2	14,000	0	0	4	.03
3	2,000	0	0	0	.0

The data in Table V illustrate the inevitable outcome of over-deposition. The leaves on which these data are based were heavily infested with eggs, No. 3 being a very small leaf. Unfortunately this wholesale mortality is not so important a factor in the development and spread of the citrus white fly as in the case of the cloudy-winged white fly, since the habit of the female leads her to scatter her eggs over the older as well as over the more tender growth. With the former species on more than one occasion effective control has been observed to follow certain favorable conditions as to the relative abundance of the adult insects and new citrus growth. It has been computed that the larvæ hatching from the 13,882 eggs deposited on Leaf No. 1, would require about 25 times the surface of that leaf in order to reach the pupal stage should they settle with the view of utilizing the least possible space. Since the larvæ do not show such discrimination in locating themselves, an even larger amount of leaf surface would be required.

Because of this lack of discrimination in settling, it will be readily seen, death due to overcrowding is not, strictly speaking, always the result of overdeposition, but frequently results from the overlapping of larvæ and pupæ during growth on leaves only moderately infested. Since, after settling, the immature stages do not change their location, specimens having ample room during the early larval stages become so large in the pupal stage, if not before, that they may overlap each other at the molting period, with disastrous results to the individual beneath. Partial overlapping of the posterior portion of a pupa does not always result in its death, but death invariably follows the overlapping of the anterior or head end of the body.

EFFECT OF CURLING AND DROPPING OF LEAVES FROM DROUGHT.

Data collected during an unusual period of drought extending throughout the fall and winter of 1906-7 show that curling of leaves as an effect of drought has little effect on the vitality of the fly at this season. In March, 1907, pupæ of the citrus white fly were observed on leaves which had been curled and dry from the effects of droughts for more than three months. The leaves were so dry that they felt and tore much like paper, but they soon regained their normal texture after the beginning of the rains. The emergence of the adults on trees affected as here described was delayed for several weeks as compared with unaffected trees, but aside from this there was no apparent effect on the insects.

Although the curling of the leaves of citrus trees as a result of drought has not, so far as observed, resulted in checking the white flies, the dropping of the leaves may be decidedly effective in this respect. When citrus trees suffer from the effects of drought to the extent of shedding a considerable part of their foliage, the resulting reduction in the numbers of white flies rarely proves of sufficient advantage to offset the injury to the trees, and the insects as a rule resume their normal status fully as rapidly as the trees recover.

BACTERIAL DISEASES.

While no bacterial disease has been recognized as such in producing the very high rate of mortality often occurring among the larvæ and pupæ of both species of white flies, there are indications that bacteria play a more important rôle in this connection than has been suspected, and are at times more beneficial in holding the fly in check than are the fungi. The fluctuating effectiveness of the unexplained mortality heretofore discussed, without the visible appearance of any fungous parasite which might be responsible, seems to indicate that some parasitic organism is directly concerned.

FUNGOUS DISEASES.

THE RED FUNGUS.

(*Aschersonia aleyrodis* Webber.)

HISTORY.

The red fungus was first discovered at Crescent City, Fla., in August, 1893, in the grove of Mr. J. H. Harp, by Dr. H. J. Webber, then of the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture, who, in a preliminary notice¹ of its entomogenous nature, referred it to the closely allied species *Aschersonia tahitensis* Mont. In 1896, under the same name, he mentions it in the bulletin "The Principal Diseases of Citrus Fruits in Florida."² Upon further study, however, he found it to be a distinct species, and in 1897, in his bulletin on the "Sooty Mold of the Orange and its Treatment,"³ described it as *Aschersonia aleyrodis*, and illustrated it with 14 line drawings and 2 colored figures. It is interesting to note that at the time Prof. Webber first reported this species attacking white-fly larvæ and pupæ no species of the genus *Aschersonia* had been known to attack insects, although several entomogenous species have since been discovered. In the last-mentioned bulletin the author, besides discussing at length the development of the red fungus on the white fly, the probable methods of spore dissemination, and methods of introduction into noninfested groves, states that he had found fungus only at Crescent City, Citra, Gainesville, Panasoffkee, Bartow, Manatee, and Fort Myers, Fla., while no fungus was seen in white-fly groves at Ocala, Orlando, Evinston, and Ormond. He further states that the fungus was very abundant in groves at Panasoffkee and that while in 1893 no trace of it could be found in the grove at Citra, it had been reported by growers as being quite abundant there in certain localities at the time of the first freeze, which occurred December 28, 1894. Since the publications mentioned above, the yearly reports and numerous bulletins of the Florida Experiment Station and the Transactions of the Florida Horticultural Society have contained the principal contributions to the literature of this species of fungous parasite. Special mention should be made of the work of Dr. E. W. Berger and Prof. H. S. Fawcett. From a technical standpoint the most important contribution to our knowledge of this fungus since Webber is contained in Prof. Fawcett's paper on "The Fungi Parasitic upon *Aleyrodes citri*,"⁴ in which the author gives the description, history, methods of introduction, distribution, and

¹ Journal of Mycology, vol. 6, no. 4, p. 363, 1894.

² Div. of Veg. Phys. and Path., Washington, D. C., ^{*}Bul. 8, p. 27, 1896.

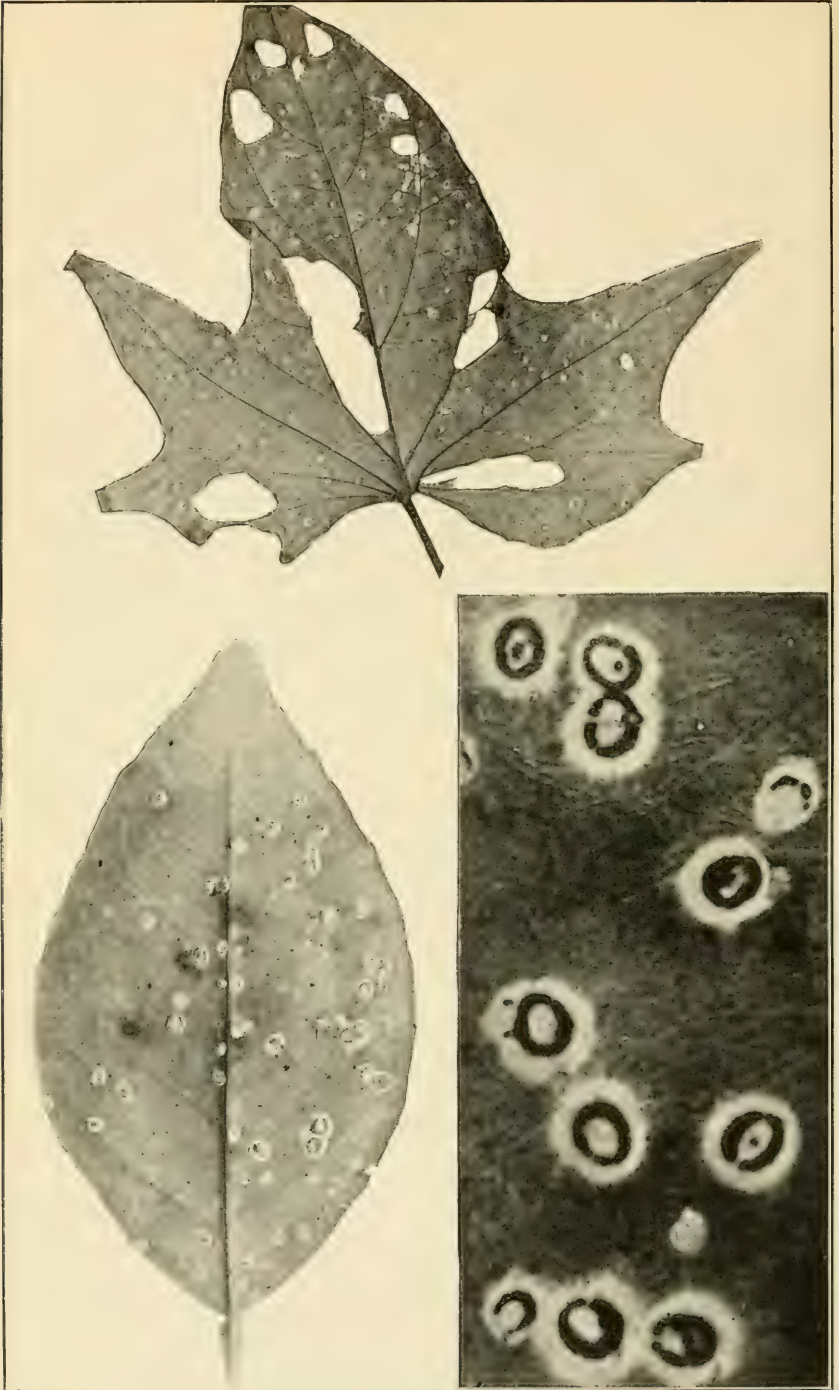
³ Div. of Veg. Phys. and Path., Washington, D. C., Bul. 13, p. 21, 1897.

⁴ University of the State of Florida, Special Studies, No. 1, pp. 10-17, 1907.



ORANGE TWIG INFESTED WITH CITRUS WHITE FLY, SHOWING A SUCCESSFUL INFECTION
OF RED FUNGUS.

[Hundreds of white flies may develop to maturity on a twig as well infected numerically as this one,
or the mortality may be complete. (Original.)]



FUNGUS-INFECTED WHITE FLIES.

[Red *Aschersonia* developing on *Aleyrodes inconspicua* infesting sweet-potato leaves (top); red *Aschersonia* infecting the cloudy-winged white fly (*Aleyrodes nubifera*) (lower left); red *Aschersonia* pustules, enlarged, showing mycelium and pycnidia (lower right). (Original.)]

valuable data on cultural methods and on the introduction of artificially grown spores. Dr. George F. Atkinson, of Cornell University, was successful in growing cultures of this fungus during the summer and fall of 1907 from material sent him by Mr. Worsham, at that time an agent of this bureau, and under date of September 30, 1907, sent the authors at the Orlando Laboratory cultures from which infections were secured in the grove.

DESCRIPTION.

A glance at Plate I, middle figure, would give one unfamiliar with this fungus a sufficiently correct idea of its appearance and make possible its identification in the grove. (See also Plates III and IV.)

Dr. Webber's original technical description is as follows:¹

Stroma hypophyllous, depressed hemispherical, pinkish buff or cream colored, coriaceous, 1-2½ mm. in diameter; mycelial hypothallus grayish white, forming a thin membrane closely adhering to the leaf and extending about 1 mm. beyond the stroma; perithecia membranaceous, at first superficial, later becoming irregular, reniform or orbicular in mature specimens, and opening by small, round, or elliptical pores or slits; basidia crowded, filiform, slender, continuous, 28-40μ long, 0.94-1.5μ in diameter; paraphyses abundant, slender, projecting beyond the basidia, 65-100μ long, ¾-1μ in diameter; sporules fusiform, continuous, mucilaginous, hyaline, sometimes obscurely 3-4 guttulate, 9.4-14.1μ long by 0.94-1.88μ wide, very abundant and erumpent, forming conspicuous coral-red or rufoous masses. (Parasitic on *Aleyrodes citri* R. & H., infesting citrus leaves in Florida.)

Dr. Webber further states that peculiar darkened cells occur at irregular intervals in the paraphyses which are quite characteristic of this species of fungus.

DEVELOPMENT.

If in the process of dissemination the spores find a favorable resting place and the weather conditions permit, they soon germinate or grow by sending out rootlike processes known technically as hyphæ or mycelial threads. Should one of these succeed in finding a vulnerable spot in a white-fly larva or pupa, the growth of the fungus becomes very rapid and the insect is soon killed. The following description of the development of the fungus within the insect has been taken, with slight changes, from that of Dr. H. J. Webber,² which in the main has been verified by the authors.

The first indication of the effect of the fungus on the larva of the white fly is the appearance of slightly opaque, yellowish spots, usually near the edge of the larva. In the early stages of infection the larva becomes noticeably swollen and appears to secrete a greater abundance of honeydew than normally. As the fungus develops, the internal organs of the larva appear to contract away from the margin, leaving a narrow circle, which then becomes filled with the

¹ Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., p. 21, 1897.

² Idem, pp. 23-24, 1897.

hyphæ or mycelium. This circle becomes opaque and whitish, presenting a very characteristic appearance. Shortly after this the hyphæ burst out around the edge of the larva, forming a dense marginal fringe. This may form all around the larva at about the same time, or may develop at one portion of the margin sooner than at the others. The body of the larva at this time is plainly visible, but it is opaque and yellowish throughout. Death usually ensues, it is believed, before the hyphæ burst out. The fungus does not spread over the leaf to any great extent, but grows upward in a mass, gradually spreading over the larva. It is not uncommon to find the perithecia, with their bright coral-red masses of sporules, formed in a circle around the edge of the larva while it is yet visible. As the *Aschersonia* develops, the hyphæ spread over the larva, forming a dense, compact stroma, which ultimately entirely envelops the larva. The stroma in this stage is thin and disklike, the fructifications being usually borne in a circle near the edge. The hymenium at this time is spread out on the surface of the stroma, or but slightly sunken, the sporules projecting in a conical coral-red or rufous mass. As the fungus develops the stroma becomes thickened and hemispherical and the hymenium gradually becomes immersed. The hyphæ which make up the main mass of the stroma are from 3.5 to 7.5 micromillimeters in diameter. Within the body of the insect and near the perithecia they are somewhat smaller.

Data collected in connection with experimental work in the field have shown that well-developed pustules can mature within 15 days after artificial spreading of the infection. Ten shoots on the outside of a tree which were sprayed on June 25, 1909, had developed by July 10 numerous well-developed pustules (red *Aschersonia*). Check shoots produced no fungus growth. The range in temperature during this period was from 70° to 95° F. (average daily mean, 80.5° F.) and frequent showers fell. Fungus introduced by spraying on July 27, 1907, had produced pustules by August 17, or 21 days later. During this period the temperature ranged from 70° to 98° F. (average daily mean for period 80.8° F.), with numerous showers. In both of these instances no earlier examinations were made. In another instance a larva of *A. citri*, noted to have died on October 15, 1908, began to develop a whitish appearance on October 23, or 8 days later, and while the fungous growth was daily observed the characteristic reddish color of the spore masses of red *Aschersonia* did not appear until November 4, or 12 days after the fungus first began to be visible to the eye and 20 days after the larva was recorded as having died. During the 20-day period the temperature ranged from 45° to 85° F. (with an average daily mean of 70.4° F.) and there was no rain. The average daily mean humidity for the three periods was 92.3, 89, and 90 per cent, respectively.

Prof. H. S. Fawcett¹ has found that this fungus requires from 30 to 40 days to mature a pustule and produce pycnidia when grown on a 5 to 10 per cent glucose agar in the laboratory.

DISSEMINATION OF SPORES.

Various agencies, such as rains and dews, crawling and adult white flies, and other insects, have been considered as probable means of spreading fungous spores. Notwithstanding the fact that its spores have been described as mucilaginous, and therefore would not seem to be subject to being blown about by winds, laboratory tests have shown that after water solutions of spores have been dried on a hard surface the spores can be loosened and blown away by the aid of an electric fan or lung power. While complete success did not attend these experiments, it was demonstrated that spores can be and doubtless are blown about by winds to a considerable extent after once being freed from their mucilaginous matrix by rains and dews, and it is believed by the authors that winds are the most valuable agents in spreading the fungus from tree to tree and to the more isolated groves in a fungus-infested district. However, when once the white flies in a tree have become infected, rains and dews appear to be the most valuable agents of distribution throughout the individual and closely adjoining trees. The fact that the pustules are largely borne on the underside of the leaves is no argument against this view. While the pustules thus located are for the most part protected from the direct wash of beating showers, examination of citrus trees, especially oranges and tangerines, will show that many of the leaves are more or less slightly curled so that their underside is easily wetted, either entirely by direct rainfalls or in spots by splashing from closely growing leaves, while the newer growth, upon which infestation is usually very heavy, because of its more flexible nature is soon beaten or weighted down by the rain so that the underside of its leaves receive innumerable splashings and drippings from the pustule-bearing leaves above.

After several showers of moderate duration and force, an examination of trees in the laboratory grove showed that about 90 per cent of the leaves were either thoroughly or partly wetted on the lower surface, and during the progress of ordinary showers drippings from leaves above have been seen to bound off from lower leaves to which they had fallen and strike the exposed underside of leaves 3 feet to one side, or to splash obliquely upward as high as 1 foot. This upward spattering accounts not a little for the upward spread of fungus. It requires only a microscopic examination of drippings from fungus-laden trees, caught during a heavy shower, to prove that

¹Special Studies, No. 1, Univ. of the State of Fla., p. 13, 1908.

spores are not only spread about by rain but that many are washed to the ground.

It is probable that dews, and especially the heavy dews of fall, are of greatest value in moistening the pustules, thus aiding in the dissolving out of the spores from their mucilaginous matrix, so that they may be more readily transported by other agencies. After heavy dews the matrix containing the spores is so soft that portions of it will adhere to any body brought into contact with it, and not infrequently such a quantity of spores is dissolved out of the pycnidia that they spread out over the leaf for one-fourth of an inch from the pustule, as shown by the reddish coloring matter of the matrix. Because of the adhesive nature of the matrix thus moistened, it is possible, and even probable, that insects play a part in spore dissemination; yet the failure of this fungus to increase to any extent during an unusually dry period in midsummer or after the summer rains cease, even though the insects remain abundant, is regarded by the authors as significant and leads them to conclude that insects, in general, play a minor rôle in spore dissemination.

Microscopic examination of washes from the bodies of adult white flies collected on trees bearing much fungus has not disclosed the presence of the spores. Of still greater importance as direct evidence is the frequently repeated observation that leaves upon which adult flies collected from similar places have been caged, and which have been protected from rain drippings, have seldom developed fungus pustules. In this connection it is also worthy of note that water-shoots, even though more heavily crowded with adults than outside new growth, develop only a slight amount of fungus as compared with the outside growth if not so located as to be easily drenched with rains. It has been generally observed by growers as well as by the authors that rapid dissemination of spores is concurrent with summer rains, and if these fail to fall the fungi are not spread rapidly, no matter how abundant the adults may have been.

SPECIES OF WHITE FLIES ATTACKED.

While the red *Aschersonia* is most effective in its attack upon the citrus white fly and is of economic importance largely in connection with this species, it is frequently found growing upon several other species of white flies. On numerous occasions it has been observed at Orlando and other points in Orange County attacking the cloudy-winged white fly, upon which it develops into unusually large pustules. Thus far, however, attempts at introduction into groves infested only with the cloudy-winged white fly have met with failure from an economic standpoint, although in each instance an infection was secured. During the summer and fall of 1907 such a luxuriant growth of fungus upon *Aleyrodes inconspicua* Quaintance was discovered at

Orlando, on the underside of sweet potato leaves, that several bushels of leaves of this plant were picked as the easiest way of procuring a supply of fungus for experimental purposes. Mr. W. C. Temple, of Winter Park, also noted a similar attack upon a sweet potato aleyrodid, probably the species above mentioned, in July, 1909. The senior author has several times seen pustules on *Aleyrodes floridensis* Quaintance on guava at Orlando and Manatee, and on another, as yet undetermined, aleyrodid attacking Spanish mulberry at Orlando, while in 1908 Messrs. M. T. Cook and W. T. Horne reported it attacking *A. howardi* Quaintance as well as *A. citri* in Cuba.¹ The junior author has found a rank growth of this fungus on a white fly (*Aleyrodes abutilonea* Hald.) at Orlando.

DISTRIBUTION.

In Florida the red *Aschersonia* occurs in all the leading orange-growing sections infested with the citrus white fly. The fact that Dr. Webber reported it from such widely separated places as Gainesville, Bartow, and Fort Myers, is sufficient evidence to warrant the conclusion that even then its distribution was wider than known. It is being continually reported from or introduced into new localities, and at present may be said to occur in greater or less abundance in Florida in all sections infested by the citrus white fly. It is most widely distributed in Manatee, Lee, and Orange Counties.

Outside of Florida the red *Aschersonia* now occurs in different points in Louisiana, having been introduced by agents of the Louisiana Crop Pest Commission. In 1905 Mr. F. S. Earle² reported this fungus on *A. citri* in Cuba. In 1906 Mr. J. Parkin³ mentioned finding in Ceylon an *Aschersonia* closely resembling *aleyrodis* on several undetermined species of *Aleyrodes*. Dr. Berger has identified this species of fungus on citrus leaves infested with *Aleyrodes citri* from Japan,⁴ and the junior author found it attacking *A. howardi* in 1910 in both Cuba and Mexico.

HYPERPARASITIC FUNGI.

Thus far the red *Aschersonia* has not been subjected to widespread attack by hyperparasitic fungi. In sheltered places during the late summer and in the fall the pustules sometimes become overgrown by the species of *Cladosporium* mentioned more fully under the hyperparasitic fungi of the yellow *Aschersonia*. In a grove at McIntosh, Fla., examined in December, 1907, it was estimated that fully 50 per cent of the red-fungus pustules were overgrown by this hyperparasite. Old worn-out pustules are often entirely overrun late

¹ Bulletin 9, Cuban Experiment Station, p. 31.

² Primer Informe Anual de la Estacion Central Agronomica de Cuba, 1904 and 1905, p. 169, 1906.

³ Annals Roy. Bot. Gard. Peradeniya, vol. 3, pt. 1, p. 36, 1906.

⁴ Ann. Rept. Fla. Agr. Exp. Sta. for year ending June 30, 1909, p. xxxvi.

in the season by a rank growth of sooty mold (*Meliola* sp.), but this usually occurs after the fungus has ceased spreading rapidly and on pustules the majority of which would fall from the leaves before spring. On the whole these two fungi are of no practical importance in checking the spread of the red *Aschersonia* or in reducing its efficacy.

THE YELLOW FUNGUS.

(*Aschersonia flavo-citrina* P. Henn.)

HISTORY.

Specimens of a white-fly parasite from the grove of Mr. J. F. Adams, of Winter Park, Fla., sent to Mrs. Flora W. Patterson, Mycologist of the United States Department of Agriculture, in September, 1906, by Prof. P. H. Rolfs, director of the Florida Agricultural Experiment Station, were identified by Mrs. Patterson as the yellow fungus (*Aschersonia flavo-citrina*). Previously this had been discovered occurring on leaves of the guava (*Psidium*) at Sao Paulo, Brazil, in October, 1901, and described in 1902 by P. Hennigs. No insect was mentioned associated with it on the guava leaves.

Since its discovery in Florida as a parasite of *Aleyrodes nubifera* and *A. citri* it has been found in several new localities and has been introduced into others. Reports and bulletins of the Florida Agricultural Experiment Station and the Transactions of the Florida Horticultural Society contain the only references to data concerning the yellow fungus as a parasite of white flies. Prof. Fawcett has published the most important contributions to our more technical knowledge and has successfully grown artificial cultures on various media. Prof. George F. Atkinson, of Cornell University, has also successfully grown cultures from which infection has been secured in the grove by the junior author in early October, 1907.

DESCRIPTION.

The yellow *Aschersonia* in general form closely resembles the red *Aschersonia*, but is at once separated from it by the rich yellow instead of pink or red color of its well-developed pustules. A sufficiently clear idea of its appearance may be had by referring to Plate I, upper figure. (See also Plates V and VII.) During the early stages of infection it is impossible to separate these two fungi by ordinary examination; it is only after the pycnidia, with their characteristically colored spore masses, are formed that they can be readily distinguished. Prof. H. S. Fawcett states ¹ that the pustules of *A. aleyrodis* under similar conditions average less in diameter, that the pycnidial cavities

¹ Fungi parasitic upon *Aleyrodes citri*, University of State of Florida, Special Studies, No. 1.

are usually more sunken than in *A. flavo-citrina*, and that its spores are smaller. The original description follows:

Aschersonia flavo-citrina P. Henn. Stomatibus carnosus, hypophyllis, subdiscoideo-pulvinatis vel hemisphaerico-depressis, citrinis, 2-2.5 mm. diameter, pruinosis, superne punctulato-pertusis, intus subaurantiis, subiculo membranaceo, flavo; pycnidiiis immersis oblongis, paraphysibus filiformibus, flexuosis, hyalinis, 140-180x1-1.5 micr., continuis; conidiis fusoideis, utrinque acutis, continuis, hyalinis, 12-18x2 micr.; conidiophoris brevibus, hyalinis, fasciculatis.

The manner of development of the yellow *Aschersonia* upon the larvæ and pupæ is so like that already described for the red *Aschersonia* that no further mention of it need be made here.

The method of spore dissemination, so far as can be determined, is also similar to that of the red fungus.

BIOLOGY.

The yellow *Aschersonia*, except when artificially introduced, has never been found in groves infested only by the citrus white fly and so far as observed thrives only on the cloudy-winged white fly. Dr. Berger¹ reports having caused the infection of a few larvæ of *citri*, but states that this fungus did not increase in his experiments. The same experience has been had by the authors at Bradentown, Fla. It has been noted by the senior author attacking a scale insect on the leaf of sweet gum (*Liquidambar styraciflua*) at Winter Park, Fla.

DISTRIBUTION.

Up to July, 1909, this fungus has been found growing naturally at Altamonte Springs, Maitland, Mims, Oneco, Orlando, Oviedo, Wildwood, and Winter Park, Fla., and has been introduced into Buckingham, Gainesville, Lakeland, Lake City, Largo, Lemon City, Manatee, Miami, New Smyrna, Sutherland, St. Petersburg, and in the vicinity of Turkey Lake in the western portion of Orange County, Fla. Its occurrence in Brazil has already been noted.

HYPERPARASITIC FUNGI.

The yellow *Aschersonia* is subject to widespread parasitism by a greenish-brown hyperparasitic fungus identified in March, 1907, by Mrs. Patterson as *Cladosporium* sp. The attack of the latter upon the yellow *Aschersonia* was first noticed by the senior author in the summer of 1906. During the winter of 1906-7 it was estimated to have overrun 95 per cent of the yellow pustules in certain groves at Winter Park and Orlando, and has since been noted wherever the yellow *Aschersonia* occurs. The destruction of more than 90 per cent of the supply of yellow *Aschersonia* spores during the fall and winter must necessarily have a retarding influence on the spread of the fungus at the beginning of the next season for its normal spread. Frequent observations and experiments at both Winter Park and

¹ Bul. 97, Fla. Agr. Exp. Sta., p. 53.

Orlando have demonstrated, however, that ordinarily the overrunning of from 20 to 90 per cent of the pustules does not prevent the fungus from spreading rapidly when the weather conditions are favorable. The *Cladosporium* spreads most rapidly during dry weather and upon leaves bearing many pustules of the *Aschersonia*.

The yellow *Aschersonia* pustules in all ages and conditions are subject to the attack of the *Cladosporium*. (See Pl. VI.) The former is frequently so closely followed by the latter that even when spreading rapidly practically all of the *Aschersonia* pustules show the beginning of the hyperparasitic attack before they reach more than one-fourth of their normal size.

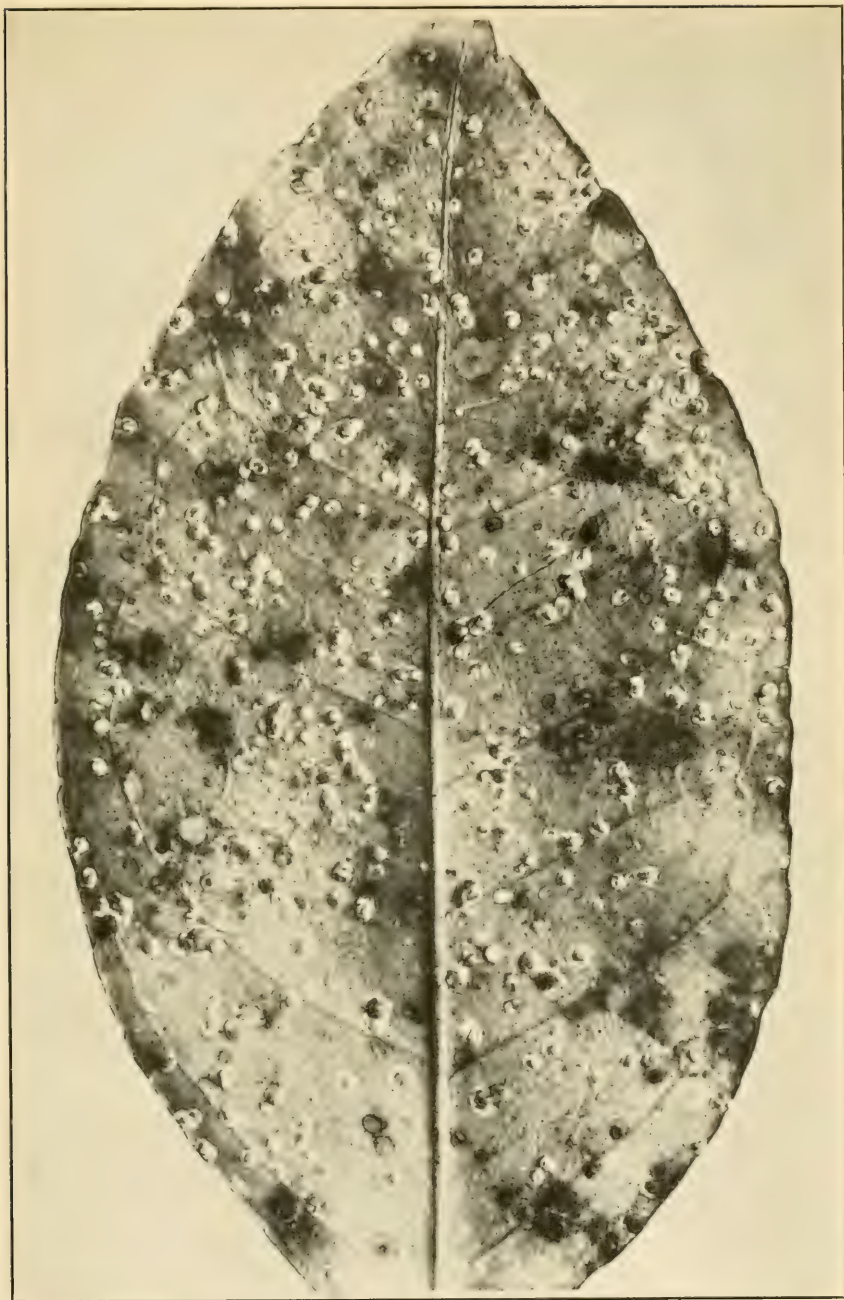
During 1907 and 1908 the *Cladosporium* was especially active in August and October. In 1907 its spread was unusually rapid between October 17 and 31, during very dry weather, and by November 15 of the same year had so overgrown the yellow fungus in one nursery at Orlando that 92.6 per cent of the pustules were affected. This estimate is based on the examination of 50 leaves upon which there were 3,110 pustules of the yellow *Aschersonia*. Again, between August 6 and 13, 1908, when no rain had fallen since July 28, it spread with such rapidity as to render useless numerous experiments started in July at Drennen. During the summer of 1909, when the rain was more abundant than during 1907 or 1908, the *Cladosporium* did not spread with such rapidity in any of the groves at Orlando.

THE BROWN FUNGUS.

(*Ægerita webberi* Fawcett.)

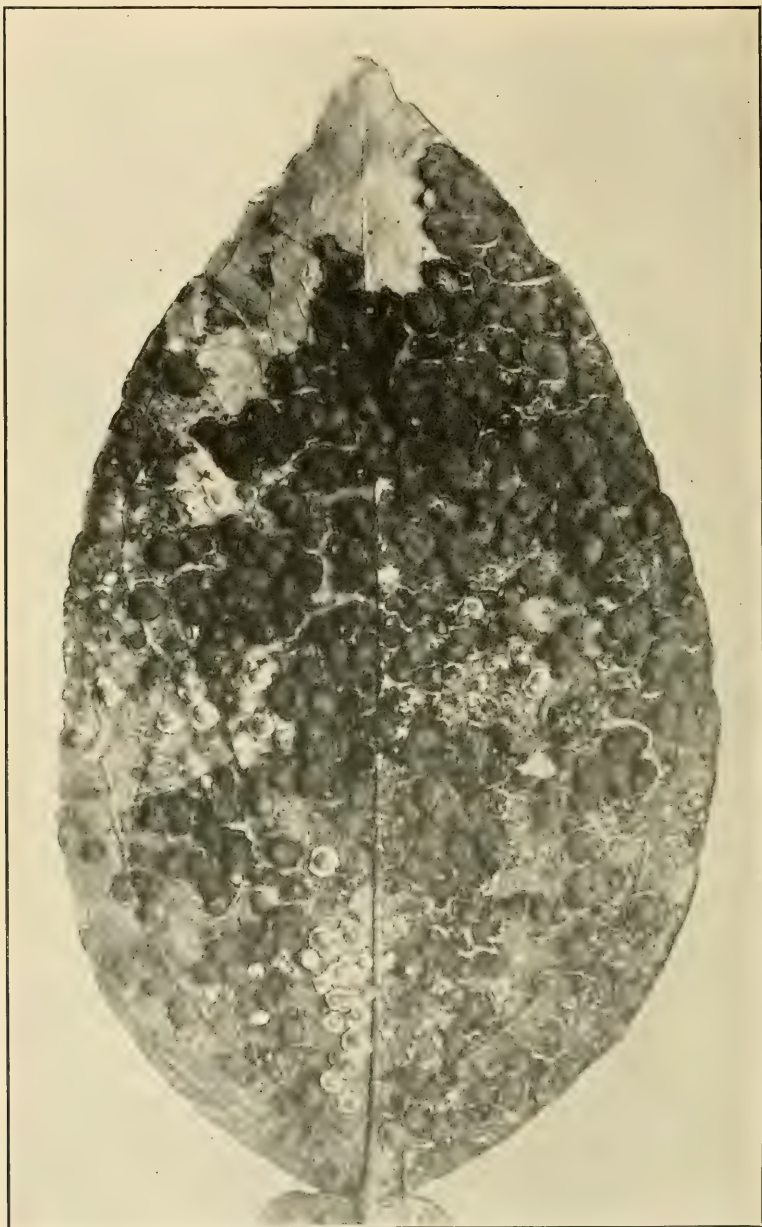
Dr. H. J. Webber, then of the United States Department of Agriculture, first discovered the brown fungus, parasitic upon the immature stage of the citrus white fly, in March, 1896, in the grove of J. H. Viser, Manatee, Fla. Dr. Webber states that while the spread of the fungus was phenomenal from March to December of that year and killed so many larvæ and pupæ that the fruit was clean, he was unable to discover it in any of the surrounding groves heavily infested with the fly. Although a thorough study of the fungus was made by its discoverer at several seasons of the year, no trace of fructification was found; hence it was impossible to determine its relationship. The fungus was, therefore, popularly named the brown mealywing fungus, or, as it is now more commonly called, the brown fungus.

During the past three years the authors have noted the frequency of the occurrence of patches of minute brownish spores on leaves infected with this fungus, arising apparently from its ground mycelium. As these spore patches occurred only upon leaves infested with the fungus and upon no other leaves no matter how heavily coated with sooty mold, it was concluded that they must be the fruiting bodies of the fungus. A specimen leaf was sent to Mrs. Patterson, the mycolo-



GRAPEFRUIT LEAF, SHOWING YELLOW ASCHERSONIA INFECTING THE CLOUDY-WINGED WHITE FLY.

[The parasitic fungous pustules are overgrown in spots by sooty mold and sooty mold is also shown developing around the edges of infected pupæ. More, rather than less, sooty mold usually accompanies as extensive an infestation by the yellow fungus as that shown on this leaf. (Original.)]



RANK GROWTH OF CLADOSPORIUM ON YELLOW ASCHERSONIA.

[All pustules of the yellow Aschersonia are destroyed except the few lighter-colored ones. (Original.)]

gist, who, under date of November 2, 1907, wrote: "The specimen has a fruiting stage connected with the brown fungus." In a publication dated October 1, 1908, Prof. Fawcett¹ announced that he had noted what appeared to be the spores of the brown fungus, and that these spores were then germinating in hanging drop cultures of sugar solutions, and were producing hyphæ that seemed identical with those of the brown fungus. Since then, however, Prof. Fawcett has been most successful in not only growing the characteristic brown-fungus mycelium from the spores, but infecting healthy white-fly larvæ with the mycelia thus grown and in securing the characteristic pustules of this fungus, to which he has given the name *Ægerita webberi*.²

DESCRIPTION.

The pustules of the brown fungus, which vary in size according to the size of the larva or pupa infected, are seal-brown in color and when fully developed entirely conceal the insect attacked. The pustules are round or slightly elliptical, and, as compared with the pustules of the red *Aschersonia*, are more flattened, thus resembling the Florida red (or circular) scale (*Chrysomphalus ficus*) (see Pl. I, lower figure; also Pl. VII.) Dr. Webber gives the following general description:³

The mature stroma is compressed hemispherical, frequently having a slight depression in the apex over the center of the insect, where the hyphæ come together as they spread from the edges of the larva in their development. The size varies greatly according to the stage of development of the insect attacked. In many young larvæ it is from one-fourth to one-half a millimeter in diameter. The thickness or height also varies in like manner, specimens on mature larvæ or pupæ having usually from 175 to 260 microns while those on young larvæ are much thinner. * * * The stroma is commonly seal brown, with a shade of chestnut, but becomes slightly darker with age. It adheres closely to the leaf, but no indication has been found that the hyphæ penetrate the latter. The hyphæ which make up the body of the stroma are light brown, very tortuous, and but slightly branched.

Those in the body of the insect are of similar character, but a much darker brown. From the base of the stroma a ground mycelium, or hypothallus, spreads out in all directions on the surface of the leaf, forming a compact membrane near the stroma, but becoming gradually dispersed into separate filaments. * * * The hyphæ of the hypothallus are colorless, sparingly branched, mostly continuous, having only an occasional septa, and are from 5 to 7 microns in diameter. In some places in the hypothallus, when the hyphæ are apparently somewhat amassed and knotted, they become light brown, similar in color to the isolated hyphæ of the stroma.

When there are but a few pustules on a leaf, the threadlike mycelium spreads as separate strands on the underside of the leaf for as far as 2 or 3 inches and may be seen with the aid of a lens. The mycelium also often extends to the upper surface of the leaf. When the pustules are abundant, however, the mycelial

¹ Univ. of the State of Florida, Special Studies No. 1.

² An important entomogenous fungus. *Mycologia*, vol. 2, no. 4, July, 1910.

³ Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., pp. 28-30, 1897.

threads interlace to form a dense papery membrane covering the lower surface of the leaf, and mycelial threads growing down the petioles and along the branch to the next leaf are often so numerous as to form a like coating on these. The authors have on many occasions seen watershoots 5 feet long with the undersides and petioles of the leaves, and the stems of the shoot, wholly coated with this dense mycelial growth. In one instance there were brownish sporelike bodies, above mentioned, scattered over the entire mycelium on the stem of the watershoot and along the edges and upper surface of the leaves. (See Pl. VII.)

DEVELOPMENT.

The development of the brown fungus on the larvæ and pupæ does not differ materially from that of the red and yellow *Aschersonias* already described, with the exception that after the hyphæ have filled the insect body and have broken out around the edges, the stroma which then forms does not produce fruiting bodies but from them there grow out slender mycelial filaments which extend to a greater distance than those of the *Aschersonias* and partly take the place of the spores of the latter in infecting other larvæ and pupæ. As with the other fungi, insects may be killed without the formation of the characteristic complete stroma, or the stroma may be restricted in its growth to the margin of the insect. Often when several insects close together are infected, one large irregular stroma will develop over them all.

The junior author has followed from day to day the growth of the mycelium of the brown fungus toward dead pupæ, and the subsequent development thereon of the characteristic stromas. This fungus is therefore definitely known to be partially saprophytic. This was previously suspected, since on leaves infected by it nearly all specimens within reach of the mycelium are overgrown and the usually large percentage of specimens dead from unknown causes is not apparent. The stroma frequently does not develop normally except around the margin, leaving the greater part of the body of the insect and the segmentation easily distinguishable. This condition is probably due in some cases to the effect of dry weather on the growth of the fungus, but it is considered by the authors to be due more often to the development of the fungus on the body of a dead insect.

DISSEMINATION.

Although Dr. Webber was unable to discover any fruiting bodies of the brown fungus, his observations led him to believe that the mycelial filaments, spreading out over the surface of the leaf from larvæ already infected, have the power to infect other larvæ and pupæ with which they come into contact, and that it seemed probable

that the spread of fungus from tree to tree was effected through fragments of the mycelium carried by wind or birds. It has been conclusively demonstrated by means of a series of marked specimens that Dr. Webber's observations as to the power of infection possessed by the mycelial filaments is correct. In several instances infection was noted to occur only so far as the mycelial growth extended. In this respect the mycelia of the *Aschersonias* is different; living pupæ have frequently been noted to touch developing pustules of both red and yellow *Aschersonia* without becoming infected.

While it is very likely that winds, birds, and insects do spread this fungus by carrying small pieces of mycelium on their bodies, the experiments of the authors and of Dr. Berger have fully demonstrated that the fungus can be spread from grove to grove by means of broken pieces of mycelium. It has been frequently observed that the fungus appears on trees to which no attempt has been made to introduce it. As yet no success has followed the attempt on the part of the authors to spread the fungus by means of the spores already mentioned, but considering the abundance with which they are developed, especially after the middle of July, it is considered probable that they play an important, though as yet unknown part in its dissemination.¹ Although it probably will be proved that the brown fungus is most widely disseminated through the agency of the small spores, it is apparent that after becoming well established on a branch its spread is due chiefly to infection started by the spreading mycelium. As noted elsewhere, these mycelial filaments have been traced from one leaf down its petiole, along the branch to the next leaf, thence along its petiole to start an infection on its underside. It is not a rare occurrence to find all the leaves on a watershoot or small branch thus connected by mycelial growths.

SPECIES OF WHITE FLIES ATTACKED.

The brown fungus thrives best on the citrus white fly and has never been observed in any amount in a grove infested by any other species. However, slight infections of the cloudy-winged white fly have been noted in various places.

DISTRIBUTION.

The brown fungus has been introduced into or reported from the following places in Florida: Lake City, St. Augustine, Hawthorn, McIntosh, Boardman, Leesburg, Orlando, Oviedo, Winter Park, Bartow, Lakeland, Largo, St. Petersburg, Bradentown, Manatee, Oneco, Palmetto, Sarasota, Alva, Buckingham, and Fort Myers. In addition it has been introduced into various places in Louisiana

¹ Since this was written Prof. Fawcett has been able to infect larvæ with mycelium grown from these spores, thus removing all doubt that they are a means of disseminating this fungus.

and Texas through the offices of the entomologists of the experiment stations of those States. Its recent discovery in India by Mr. R. S. Woglum, of the Bureau of Entomology, has been noted by Dr. Howard.¹

HYPERPARASITIC FUNGI.

A greenish hyperparasite of the brown fungus was noted by the senior author in April, 1907, in Manatee, Fla., where an examination of leaves shed by the cold of the previous winter in one grove showed that fully 95 per cent of the pustules of the brown fungus had been parasitized. Since then it has been observed at various times in many of the groves in Manatee, Oneco, and Palmetto. In September, 1907, it was noted by the senior author at Lake Charles, La., where its occurrence was directly traceable to importation of nursery trees from Manatee County, Fla.

Prof. H. S. Fawcett has identified this hyperparasite as *Coniothyrium* sp. It forms a dense, dark-greenish, hard growth over the pustule of the brown fungus and presents a surface roughened by numerous pustular elevations as shown in Plate VII.

As only the stromata of the brown fungus appear to be affected, it is doubtful if the *Coniothyrium* has any practical influence in checking the spread of the mycelium of the brown fungus. In fact, it has been repeatedly noted that even when its parasite was present the brown fungus was spreading as rapidly and doing as effective work in controlling the fly as when it was not parasitized. In January, 1909, the junior author noted that the *Coniothyrium* was rare in groves in and about the Manatee hammocks, even where it was observed to be most abundant in 1907, and in all these groves the brown fungus was doing effective work in controlling the fly.

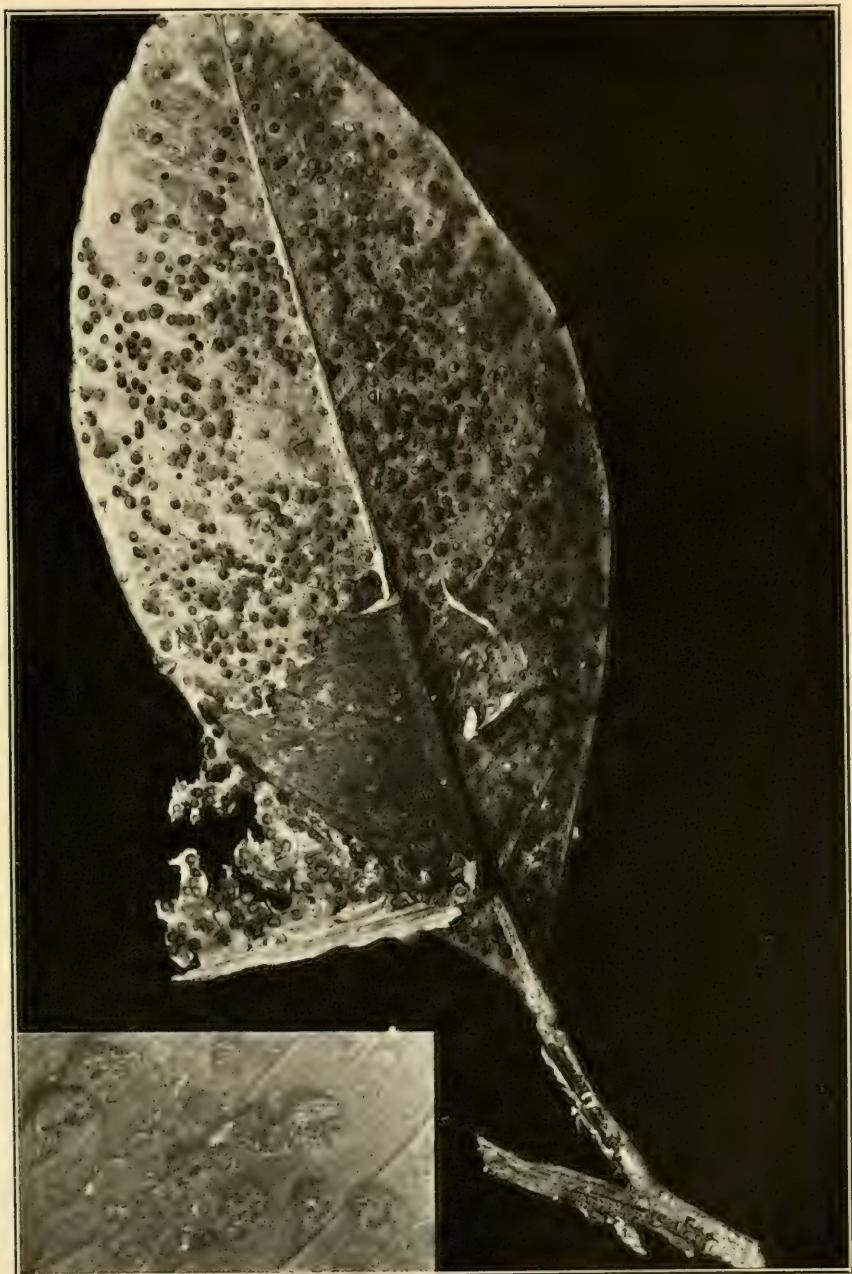
FUNGI OF LITTLE OR NO VALUE AS WHITE-FLY PARASITES.

THE WHITE-FRIDGE FUNGUS.

(*Microcera* sp.)

The white-fringe fungus (*Microcera* sp.) is so inconspicuous that it is easily overlooked. It forms no distinct pustules as do yellow and brown fungi. (See Plate IX, lower figure). Larvæ and pupæ infected turn whitish, then red, often pinkish, and from their margins bursts forth a delicate fringe of white mycelial growth from which the fungus derives its name. There subsequently appear at various points along the margin and through the vasiform orifice the fruiting bodies, which are pink in color and vary in number in different specimens infected. After the specimens infected are dried or after the mycelium has been long developed, the characteristic fringe dries up and disappears, so the best lasting evidence of the presence of this fungus is its pink fruiting

¹ Journ. Econ. Ent., vol. 4, p. 130, 1911.



LEAF SHOWING BROWN FUNGUS WHICH HAS DEVELOPED ON LARVÆ AND PUPÆ OF THE CITRUS WHITE FLY; FILM OF MYCELIUM PARTLY TORN FROM LEAF AND STEM.

[Lower figure shows Coniothyrium on brown fungus. (Original.)]

bodies. Those desiring a fuller description are referred to Press Bulletin 68, issued October 14, 1907, by the Florida Agricultural Experiment Station, by Prof. H. S. Fawcett, in which appears the original description. In June, 1908, Prof. Fawcett¹ published a more technical description, together with data on successful cultural methods and introductions secured in the field with artificially grown cultures. The apparent effectiveness of this fungus and methods of introducing it are discussed by Dr. Berger² in a publication bearing the date of February, 1909.

The authors' experiences with this fungus date from the fall of 1906. Under date of November 26 of that year the senior author noted the presence at Orlando, in a grove infested with the cloudy-winged white fly, of an "unknown pink fungus especially prevalent on pupæ killed by a spray." While no data as to the relative abundance of infected pupæ on the sprayed and unsprayed trees were collected, the number of infected specimens on the sprayed trees was unmistakably greater. Examinations made showed that from November 26 to December 10 there was no spread of fungus to previously marked healthy pupæ from infected pupæ touching them. Later in the same year this fungus was seen at Hawthorn developing upon the citrus white fly. Under date of August 27, 1907, Mr. Worsham reported the *Microcera* quite abundant in Manatee, Hillsboro, and Orange Counties, saying that at that time it was present in greater abundance in every grove visited in Manatee County than on July 19. Under the same date Mr. Worsham reported it very abundant in the groves of Mr. F. L. Wills and Mr. C. W. Hicks, at Sutherland, and in several groves at Orlando. On November 1, 1907, an examination of leaves from Mr. Hicks's grove gave the following results: Flies reaching maturity and emerging, 46.8 per cent; living larvæ and pupæ, 4.9 per cent; dead larvæ and pupæ, 4.2 per cent; dead larvæ and pupæ infected with the white-fringe fungus, 44 per cent. Under date of November 11, 1907, a grower at Largo reported that this fungus had killed 95 per cent of the fly in his grove, but an actual count of the leaves sent to the Orlando laboratory with this statement showed that 12.9 per cent had reached maturity and had emerged, 52.7 per cent were still alive on the leaves, and 34.3 per cent were dead from fungus and unexplained mortality, no attempt being made to find the percentage of white-fringe fungus, which was noted as being very slight.

On October 3, 1907, many pupæ of *Aleyrodes nubifera* were killed by mechanical injuries in applying as a smear a culture of yellow *Aschersonia*; on October 31 the junior author noted that many pupæ had been killed by the application of the culture, and on November

¹ Fungi parasitic upon *Aleyrodes citri*. Univ. of State of Florida, Special Studies, No. 1.

² Bul. 97, Fla. Agr. Exp. Sta., pp. 54-55.

11 that these same dead pupæ had developed the characteristic growth known as white-fringe fungus. During 1908 and the summer of 1909 the authors found the fungus in every grove visited in various parts of the State.

Since the observations made on November 26, 1906, this fungus has been regarded by the authors as entirely or largely saprophytic, and all data and observations since obtained have strengthened this belief. Three series of observations have been conducted in connection with fumigation experiments. The data obtained are presented in Tables VII and VIII. Specimens of the fungus under observation were submitted to Prof. H. S. Fawcett, who verified the authors' determination of the species. The data in Table VI are based upon the examination, by the senior author and Mr. W. W. Yothers, of leaves picked promiscuously from adjoining fumigated and unfumigated rows of nursery trees. The trees were fumigated on September 26, 1908, and the examination was made on October 8, 1908.

TABLE VI.—*Relative abundance of white-fringe fungus on fumigated and unfumigated leaves.*

Leaves.	Number of leaves examined.	Live pupæ.	Dead pupæ.	Pupæ infected with white-fringe fungus.		
				Total.	Average per leaf.	Per cent.
Unfumigated.....	20	2,154	1,031	29	1.4	0.9
Fumigated.....	20	19	4,432	302	15.1	6.8

In Table VII are given data collected by Mr. Yothers showing the development of the fungus over a period of one month on fumigated leaves, as compared with the same on unfumigated leaves. Five selected leaves were under observation in each case.

TABLE VII.—*Development of white-fringe fungus on fumigated and unfumigated leaves.*

Fumigated October 12, 1908. ¹				Unfumigated. ²			
Leaf No.	Pupæ infected on—			Leaf No.	Pupæ infected on—		
	Oct. 13.	Oct. 26.	Nov. 9.		Oct. 13.	Oct. 26.	Nov. 9.
1.....	0	1	2	6	0	0	0
2.....	1	4	12	7	3	4	4
3.....	4	8	8	8	1	3	3
4.....	1	13	20	9	0	0	0
5.....	0	1	29	10	1	4	4
Total.....	6	27	61	.....	5	11	11

¹ Leaves 1 to 3 on one nursery tree with a total of 400 dead and 2 living pupæ. Leaf No. 4 on similar tree and with same number dead and living pupæ. Leaf No. 5 on similar tree but with 1 living and 400 dead pupæ.

² Leaves 6 to 10 with average of about 40 living pupæ and numerous dead larvæ and pupæ per leaf.

In the third series of observations the junior author selected leaves on which all living pupæ had been killed by fumigation. It is probable that fungus had already infected a few dead pupæ but had not broken out around the margin previous to fumigation; yet, considering the comparatively few pupæ becoming infected on unfumigated leaves as compared with the unusual number infected on fumigated trees, there is no doubt that the fungus developed for the most part after the pupæ were killed by the gas.

TABLE VIII. — *Development of white-fringe fungus on leaves fumigated Sept. 26, 1906.*

Leaf No.	Pupæ alive.	Pupæ dead.	Pupæ infected with white-fringe fungus on—					
			Sept. 30.	Oct. 8.	Oct. 14.	Oct. 21.	Oct. 28.	Nov. 5.
1.....	0	200	0	10	32	57	57	57
2.....	0	600	0	0	2	21	40	40
3.....	0	200	0	0	8	21	48	48
4.....	0	400	0	0	1	10	22	22
5.....	0	100	0	0	1	6	6	6
Total.....	0	1,500	0	10	44	115	173	173

Concerning the reported practical results in reducing the white flies, it may be said that the occurrence of a very high percentage of the dead larvæ and pupæ, especially of the cloudy-winged white fly, as already noted in the grove of Mr. C. W. Hicks, where over 91 per cent of the dead insects were infected, has no bearing on the parasitic nature of this fungus, since an equally high rate of mortality occurs in groves infested with the same species where very little white-fringe fungus can be found. Its prevalence is evidently only an indication of the extent of the occurrence of unexplained mortality. The data here presented are regarded by the authors as satisfactory evidence that the *Microcera* develops almost entirely or exclusively on larvæ and pupæ already dead from other causes and should be disregarded as a factor in the control of the white fly.

SPOROTRICHUM.

The *Sporotrichum* is either closely related to or identical with one of the diseases of the chinch bug which attracted so much attention from entomologists a number of years ago. As a white-fly parasite it has been under observation since September 8, 1906, and is largely limited in its spread to the fall of the year, when, under favorable weather conditions, it spreads with astonishing rapidity among adults of both the citrus and cloudy-winged white flies then crowding the new growth. This fungus does not form pustules like the red *Aschersonia*. Adults killed by it remain attached to the underside of the leaf, their bodies become shriveled, and in a short time the grayish mycelial threads of the fungus break through the body of the fly and

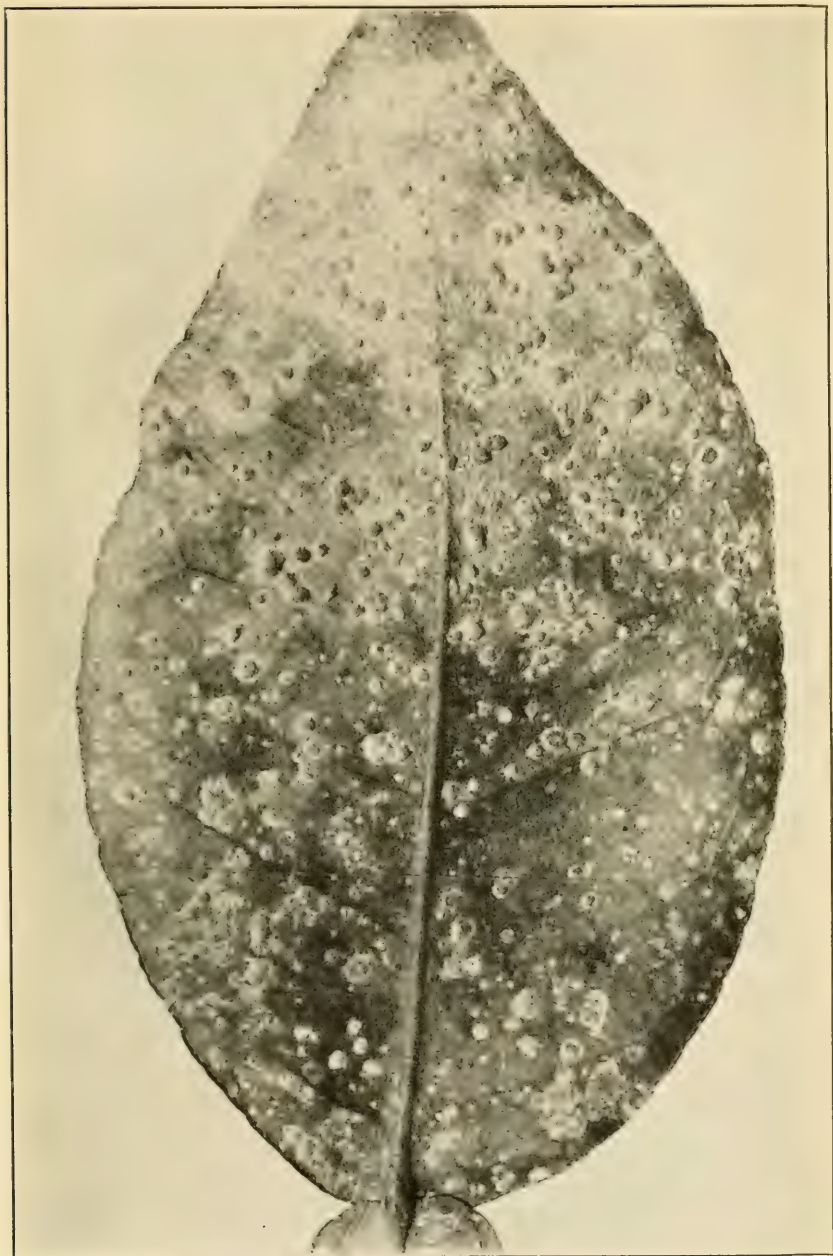
produce countless spores. To the casual observer the flies appear merely to die and shrivel up on the leaf as shown in Plate IX, upper figure.

In connection with this fungus the authors' observations have been limited to the vicinity of Orlando, but Prof. Fawcett, to whom credit is due for its determination, has seen it several times working in different parts of the State since August, 1908. While it has been reported by Dr. Berger¹ as attacking the larvæ of the citrus white fly, and has been seen by the authors attacking the eggs of the same species, it must be regarded, so far as now known, as primarily a parasite of the adult.

Notwithstanding the very large number of adults it is capable of killing when spreading most rapidly during the fall, it can not be said that it has proved itself of any value in checking the progress of fly infestation for the reason that a sufficiently large number of adults escape to deposit as many eggs as the new growth can well support. During September and early October, 1908, when this fungus was spreading very rapidly and there were in places from one to several hundred dead flies per leaf and it appeared that much good was being accomplished, careful examination of the leaves of the new growth showed that they were heavily infested with eggs. In a grove near Turkey Lake, 8 miles west of Orlando, where the *Sporotrichum* was even more virulent in its attack upon the cloudy-winged white fly, the surviving adults so overcrowded the leaves with eggs that on many shoots not a larva was able to mature. These observations have been mentioned to show that, if anything, the killing of an even comparatively large number of the fall brood of adults may act as a stimulus rather than a check to the progress of infestation, inasmuch as it seeks to prevent that overdeposition of eggs, which, in itself, as explained elsewhere, is an important element of self-control with this species.

Thus far the authors have not been successful in attempts at spreading the *Sporotrichum* artificially. During September, 1908, many thousand infected flies were collected for experimental purposes. On October 8, when the fungus was spreading less rapidly than during September, two watershoots were rubbed with infected flies, and although adults of both species fed on the leaves for two weeks none became infected. One hundred adults caged on a leaf smeared with a paste made of 100 infected flies and water did not become infected, neither did adults confined on leaves sprayed with a solution of 100 infected flies in one-fourth of a cup of water. Experiments with the same material on May 29 and August 17, 1909, gave equally negative results, although adult *citri* were abundant on the treated leaves. Leaves of china tree and orange were dipped and sprayed with a water solution of infected flies, were rubbed with a paste made of flour and

¹ Bul. 97, Fla. Agr. Exp. Sta., p. 56, 1909.



CINNAMON FUNGUS, SHOWING PUSTULES AND THE DENSE WHITISH MYCELIUM FORMING IN PLACES A FELTLIKE COVERING ON UNDERSIDE OF LEAF. (ORIGINAL.)



UPPER FIGURE, SPOROTRICHUM FUNGUS INFECTING ADULT WHITE FLIES, CAUSING THEM TO REMAIN ATTACHED TO UNDERSIDE OF LEAF, INSTEAD OF DROPPING AS IS USUAL.

LOWER FIGURE, LARVÆ AND PUPÆ OF THE CITRUS AND CLOUDY-WINGED WHITE FLIES KILLED BY FUMIGATION AND LATER DEVELOPING THE WHITE-FRIDGE FUNGUS. (ORIGINAL.)

infected flies, and, both wet and dry, were dusted with a mixture of infected flies and flour applied with a blowgun. No fungus developed on cheeks kept on these experiments.

THE CINNAMON FUNGUS.

(*Verticillium heterocladium* Penz.)

History.—The cinnamon fungus (*Verticillium heterocladium*) was first described by O. Penzig in 1882 attacking the soft scale (*Lecanium Coccus hesperidum* L. on lemon leaves in Italy. In 1905 Dr. E. H. Sellards, then entomologist of the Florida Experiment Station, found it growing on *Aleyrodes citri* at Palmetto, Fla., on leaves also bearing numerous pustules of the brown fungus. As no fruiting bodies of the latter had ever been found, for several years it was thought possible that it might be the spore-bearing stage of the brown fungus. However, it has since been proved distinct by Prof. H. S. Fawcett, who has referred it to Penzig's species, and in 1908 published the results of his studies begun in 1905, giving an account of its history, its description, and biological notes.

Description.—The pustules of this fungus are brownish-gray or cinnamon colored and are surrounded by a whitish feltlike growth spreading out over the leaf for a short distance around the pustule. In general appearance, when not growing luxuriantly, this *Verticillium* superficially resembles the brown fungus. The following technical description is quoted from Prof. Fawcett:¹

The pustules, which are cinnamon colored, are powdery on the surface. Under the hand lens they appear brushlike in form, bristling with hyphae. From the edge of the pustules there grows out a creeping layer of white, delicate, interwoven hyphae. From these colorless hyphae, as well as from the top of the pustules, there arise upright conidiophores. These may have either a simple series of whorls, two to four branches in each, or the branches of the whorls may again be whorled. The conidia are borne on the ends of the ultimate branches. The conidiophores are quite delicate, slender, hyaline, 150 to 240 microns by 3 to 4 microns, several times septate. The conidia are oblong, hyaline, 4 to 6 microns long by 1.5 to 2.5 thick. The main body of the cinnamon-colored stroma when mature becomes powdery in appearance, and under the microscope it is found that the hyphae have broken up into short pieces irregular in shape and length with rounded ends, some of them quite closely imitating spores. These have thicker walls than the conidia, and probably act as reproductive bodies in carrying the fungus through a period of dry weather.

The resemblance to the brown fungus mentioned above is most striking when the pustules are very scattering and only partially developed. However, when very abundant, as shown in Plate VIII, the similarity between the two fungi disappears. Leaves have been found in which the underside was entirely concealed beneath the feltlike mycelial growth surrounding the pustules. This running together of the mycelial growths of the several pustules is shown in

¹ Special Studies No. 1, Univ. of Florida, p. 23, 1908.

places in Plate VIII. When weathered the pustules lose their powdery appearance and their surface appears pitted. This fungus attacks both the larval and pupal stages of both the citrus and cloudy-winged white flies, and has been observed by the junior author to spread to and develop pustules on larvæ and pupæ known to be previously dead. It is therefore saprophytic as well as parasitic.

Effectiveness.—The authors have frequently observed this fungus in various places in Lee, Manatee, Orange, and Marion counties since 1906, but in only one instance, on a few nursery trees in a very moist spot at Orlando, did it appear to give promise of ever being of value in holding the fly in check. The pustules are usually very scattered, being most abundant in the lowest and most shaded portions of the grove. Considering the almost negligible good accomplished by it, it has not been the subject of serious study in the course of these investigations except in noting its spread on certain trees to both living and dead marked larvæ and pupæ. Prof. Fawcett has successfully grown cultures on various media, and both he and Dr. Berger have secured infections in the grove with these cultures.

Distribution and insects attacked.—The cinnamon fungus has been reported as infecting *Aleyrodes citri* at Gainesville, Citra, McIntosh, Orlando, Winter Park, Apopka, St. Petersburg, Palmetto, Bradentown, Manatee, Oneco, Bartow, Fort Myers, Buckingham, and Alva. Its attack is not restricted to the citrus white fly. Prof. Fawcett states that it has been found in Florida on the following five scale insects: *Lepidosaphes gloveri* Pack., Gainesville; *Diaspis* sp., on leaves of *Euonymus americanus*, Gainesville; *Lepidosaphes beekii* Newm., Palmetto and Citra. In Italy it attacks soft scale (*Coccus hesperidum*) on lemon leaves, and in Africa and the Antilles it has been reported on unknown host insects.

THE REDHEADED SCALE FUNGUS.

(*Sphærostilbe coccophila* Tul.)

The red-headed scale fungus (*Sphærostilbe coccophila*) is here recorded among those fungi of minor importance attacking the white fly only because it has been repeatedly associated with it in this connection. It was first noted as a parasite on *Aleyrodes citri* at Orlando in 1903 by Prof. H. A. Gossard. While it has a world-wide distribution and is very effective at times as a parasite of scale insects, being reported on no less than 15 species, its value as a parasite on the citrus and cloudy-winged white flies is absolutely nil. Probably not more than one white-fly larva or pupa in a million is killed by it. In not a few cases, where it has been thought on casual observation to be attacking the white-fly larva, careful examination with a lens has shown that its bright red fruiting bodies originated not in the fly larva itself but in a purple scale, *Lepidosaphes beekii* Newm., partially or completely concealed by it.

NATURAL EFFICACY OF FUNGOUS PARASITES.

Under this heading are discussed subjects relating to the actual degree of control of which fungous parasites have shown themselves capable, without regard for the possibilities of increasing that degree of efficacy by artificial means. These two subjects are frequently confused, although a clear distinction is necessary for a proper understanding of the economic value of the parasitic fungi.

CREDIBILITY OF COMMON REPORTS.

It is a well-recognized fact among economic entomologists that wherever predaceous insects or parasites of any kind are conspicuous enemies of an insect pest, popular reports are greatly exaggerated in regard to the efficacy of the natural enemy. The amount of control influence exerted by the natural enemy can not be approximated by casual observation, by the record of parasitism of a comparatively small number of specimens of the insect pests, or even by the seemingly practical results as shown by the condition of the host plant. A casual observation summarized by a statement that 50, 75, or 90 per cent of the insects are destroyed by fungous parasites is usually worthless and misleading. Even an experienced entomologist could not make a statement of value in this respect without first making extensive counts of specimens, recognizing the influence of unexplained mortality and the effect this has upon the apparent percentage of parasitism. The experience of the authors in the course of the investigations reported herein shows that thousands of insects rather than hundreds, and these on leaves picked absolutely at random without previously making any note of their condition, can be regarded as the only satisfactory basis for approximate estimates of the efficacy of fungous parasites. Even reports based on seemingly practical results of fungous parasites, with the white flies greatly reduced and with clean leaves and fruit, should not be credited without being authoritatively confirmed.

Experience has shown such reports too frequently to be incorrect for either of two reasons: The first is due to a misunderstanding of the factors influencing fluctuations in numbers of the insects; the second is the absolute lack of any actual foundation for the popular report of the character referred to. These reports are traceable to a feature of human nature which is found everywhere. One can not become well acquainted with the white-fly situation without noting instances of persistent and emphatic reports in regard to the complete efficacy of fungous parasites in certain sections or in certain groves which upon investigation are found to be entirely erroneous.

It is desirable that citrus growers become acquainted with all important facts in regard to the white flies and the methods of their

control, but due weight should be given to the authoritativeness of common reports. Otherwise the confusion which arises becomes a decided hindrance to progress.

OLDER ESTIMATES OF THE NATURAL EFFICACY OF FUNGOUS PARASITES.

In some respects the subject of the natural efficacy of the fungous parasites of white flies is the most important subject dealt with in this bulletin. Common reports concerning this matter are so frequently erroneous or misleading, as has just been explained, that in addition to the specific observations and records to be given under another heading it is considered advisable to present here quotations from previous publications showing the status of the fungous parasites at different periods since their discovery and the views expressed by various writers concerning their efficacy.

In a publication previously referred to, submitted for publication in March, 1897, Dr. H. J. Webber makes the following statement:¹

The writer believes it may safely be assumed that the spread of *Aschersonia aleyrodis* and the brown mealy wing fungus will ultimately materially check the ravages of the mealy wing (white fly) and sooty mold.

According to the publication mentioned, Dr. Webber knew of two instances of apparently satisfactory control resulting from the red *Aschersonia* and one such instance resulting from the brown fungus. Owing to the comparatively brief period of his observations and to the checking of both the white fly and its parasitic fungi by the freezes of December, 1894, and February, 1895, the fact that the parasites did not maintain a uniform state of control apparently had not come under Dr. Webber's observation at the time of writing the report from which the quotation is taken. However, as a prediction his statement was doubtless fully warranted by the circumstances.

The next investigator to give attention to the matter of the efficacy of the fungous parasites was Prof. H. A. Gossard. After more than four years of more or less continuous investigations and observations, noting the fluctuations from year to year in the abundance of the insects and of the parasites, he arrived (1903) at the following conclusion:²

I repeat emphatically that while I have no word of condemnation for the man who with intelligence and skill directs nature's agencies so that he secures results from most insects equal to the best (and we have some such in Florida), I believe that white fly is an insect that should be fought by everybody by insecticides from the day it is discovered in a grove. I admit that there is no spray that will kill white fly and not at the same time inflict injury to the trees, but I am satisfied that the injury is far less than white fly causes, except during exceptional periods when fungous diseases are unusually active. Infested trees that are properly sprayed through many years and

¹ Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., p. 34, 1897.

² Bul. 67, Fla. Agr. Exp. Sta., p. 626, 1903.

are correctly treated in other respects I believe will live longer, yield better, and give much larger net profits than they will do if fungi alone are relied upon for protection.

After three years largely devoted to investigations of the white flies affecting citrus in Florida, giving particular attention to their fungous diseases, Dr. Berger ¹ (1909) summarized his observations concerning natural efficacy of the fungous parasites as follows:

When left without assistance the fungi will practically destroy the white fly in a grove, on the average, once every three years; thus reducing the injury due to the white fly by at least one-third. The destruction is not complete, so that the insects increase again during the two succeeding years; but this is accompanied by rapid increase of the fungi, until the white fly is again overwhelmed. This is the course run by the white fly and the fungi when unassisted in those sections which have been longest infested, such as Manatee County, Fort Myers, and Orlando. At Orlando the fungi were in the ascendancy during the summer of 1906, and this resulted in so far reducing the white fly that an uncommonly large and clean crop of citrus fruit was marketed in 1907.²

Mr. C. L. Marlatt, assistant chief of this bureau, after visiting various sections of Florida in the fall of 1907 and discussing the white-fly situation with numerous well-informed citrus growers, described the natural efficacy of the red and brown fungi as follows:³

In Manatee County, where the fungi are fully established, they are able practically to exterminate the white fly once in three years, so that every third year the fruit is clean and requires no washing. The following year the insect again flourishes because the white-fly fungi have disappeared, having during the clean year nothing on which to develop. Toward the end of this year, however, the fungi again begin to operate, but not sufficiently to prevent the complete blackening of the foliage and fruit during the following or third year. Nevertheless, during this year the fly is again reduced to practical extinction, so that the year following is a year of clean foliage and fruit.

The senior author of this bulletin, writing in the fall of 1907⁴ after a little more than one year devoted exclusively to white-fly investigations, discussed the natural efficacy at some length, in part, as follows:

Data obtained from many orange growers and personal observation by the writer and other entomologists connected with the Bureau of Entomology indicate that the fungi, without artificial aid, reduce the injury from the white fly about one-third. * * * One year in three, it is the experience of the growers in this county (Manatee), the fungi have so thoroughly cleaned up the pest that the fruit is clean and requires no washing. * * * Considering the county as a whole in 1906, fully three-fourths of the groves were so free from sooty mold as to require no washing of the fruit. It was generally considered that this condition had never before been equaled since the white fly first obtained a foothold in this county. * * * As a natural consequence of the lack of abundant food for the fungous parasites in 1906, the situation in 1907 showed a complete reversal, with more than three-fourths of the groves thoroughly blackened by sooty mold. It is not uncommon to find that individual groves vary considerably from the average condition of the groves in the county as a whole.

¹ Bul. 97, Fla. Agr. Exp. Sta., p. 50, 1909.

² See explanation of this condition on p. 11.

³ Proc. Ent. Soc. Wash., vol. 9, nos. 1-4, p. 124, April, 1908.

⁴ Bul. 76, Bur. Ent., U. S. Dept. Agr., p. 64, issued October, 1908.

From the foregoing quotations it is seen that there is practical agreement among the various writers as to the natural efficacy of the fungous parasites.

OBSERVATIONS AND RECORDS CONCERNING NATURAL EFFICACY.

Under the subject of unexplained mortality it has been shown that even where fungous diseases are most effective mortality from this source is secondary in importance to that from unexplained causes. The recognition of this fact does not in any way detract from the actual value of the fungous parasites, but should be regarded as a necessary step in the proper estimate of that value.

The theoretical efficacy of white-fly fungous parasites may be determined by a similar method of calculation as that employed on page 16, in estimating the efficacy of unexplained mortality. Instead of 12.4 and 15.4 per cent for the years 1908 and 1909, the efficacy would become 47.6 and 53.2 per cent if there had been no unexplained mortality. Considering the normal rate of increase of the white flies as shown in a previous bulletin of this bureau, mortality among the larvæ and pupæ to the extent of the foregoing calculations (47.6 per cent and 53.2 per cent) obviously would be of no practical advantage as an average condition. The insects could continually maintain themselves at the maximum of injurious abundance even if the mortality were 25 or 30 per cent higher. Theoretically considered, therefore, the fungous diseases were entirely ineffective in either 1908 or 1909 for the average of the 10 groves under observation.

There is another phase of the subject to be considered, however. With unexplained mortality present in all groves it is not necessary for fungous diseases or any other known cause of mortality to increase to a point of independent efficacy in order to be of distinct value. The most important question to be considered here, therefore, is: To what extent do fungous parasites effectively supplement all other causes of mortality to the direct and practical advantage of white-fly infested citrus groves?

For practical purposes in this bulletin, fungous parasites are said to have worked effectively or to have cleaned up a grove when they appeared to have worked effectively on the insects not succumbing to unexplained causes of mortality, bearing in mind that the same rapidity of spread and multiplication and the same percentages of infection do not produce similar effects in different cases. This absence of standards of efficacy is plainly shown in the data presented in Table II and also in the following table in which the records concerning eight of the groves included in Table II are extended to show the status of the white flies and their fungous diseases at the end of the season of 1909.

TABLE IX.—*Status of white flies and their fungous parasites in eight groves, December, 1908, to December, 1909.*

Grove No. ¹	Examination, December, 1908.			Examination, July, 1909, 100 leaves picked at random from each grove; condition as to sooty mold.	Examination, December, 1909.		
	Average number forms per leaf.	Average number live forms per leaf.	Average number forms killed by fungus per leaf.		Average number forms per leaf.	Average number live forms per leaf.	Average number forms killed by fungus per leaf.
1	103.7	49.1	24.5	All leaves thoroughly blackened.	170.0	0.5	56.6
3	108.3	32.0	1.7	79 per cent moderately blackened.	124.4	13.0	12.4
4	132.6	20.0	19.2	60 per cent moderately or slightly blackened.	106.2	6.8	14.0
5	229.2	35.9	29.6	64 per cent thoroughly, 34 per cent moderately blackened.	218.5	13.8	26.0
8	597.3	30.6	80.9	None blackened.....	82.3	11.9	13.4
9	282.4	8.4	43.9	Traces of blackening.....	48.7	4.9	3.1
10	469.4	1.7	84.2	None blackened.....	56.8	3.9	11.6
12	229.9	8.3	9.7	8 per cent moderately blackened, remainder showing traces.	27.8	2.5	3.6

¹ See Table II.

As regards blackening of the fruit and foliage, which is the most important element of injury by the white flies, groves 1, 3, 4, and 5 were not benefited by the work of the parasitic fungi during either 1908 or 1909. By the 1st of July, 1909, these groves were at least as black as the average infested grove in which no fungous parasites were established. Moreover, there were sufficient live insects present to continue this condition regardless of any unusual climatic conditions which might favor the multiplication of the fungous diseases. As regards the reduction of the insects themselves, the fungous diseases were decidedly effective in grove No. 1, promising a condition of freedom from white-fly injury in 1909. The condition of groves Nos. 3 and 5 did not give promise of such condition, since any number of live white flies (pupæ) above 10 per leaf in December is strong indication that the insects will multiply sufficiently the following spring to cause a decidedly injurious blackening of the foliage and fruit before climatic conditions will give the fungous parasites an opportunity to check them. Without interference by adults migrating from other groves, an average of 12 overwintering insects per leaf has been noted to produce a general blackening (moderate) of new spring growth of foliage by June 15, while an average of 2.6 live insects per leaf in December was noted to result in a very heavy infestation one year later with excessive blackening of the foliage. As is often the case, in this latter instance the foliage appeared entirely clean up to midsummer, most of the blackening appearing in September and October.

On the July examination of No. 4 it was found that the average number of forms per leaf representing the insects which produced the condition noted consisted of 26 dead larvæ and pupæ, 8.8 live larvæ and pupæ, and 1.9 pupa cases. No. 8 was in a satisfactory

condition in July, but in December the average number of dead larvæ and pupæ was found to be 61, live larvæ and pupæ 11.9, and pupa cases 5.1. This would indicate at least a slight blackening of the leaves by the end of the year, judging from the effects of a lighter infestation in the case of No. 4 as noted above. To a casual observer this fairly satisfactory condition might appear to have resulted from fungous diseases. As a matter of fact the fungous diseases had no appreciable effect. A fairly high average number matured per leaf in the spring of 1909, but very few eggs were deposited on the citrus trees. This appeared to be due to the emergence of the insects before the appearance of new growth on the citrus trees and as a consequence the attraction of the adult white flies to other food plants, persimmon and China trees, having new foliage. An examination of a persimmon tree growing in the midst of the citrus trees on this property showed 8 times more larvæ and pupæ per leaf than on the leaves from surrounding citrus trees. If fungous diseases had been concerned in the reduction of the infestation of the citrus trees the July examination of the spring growth would have shown this. The examination of 100 leaves picked at random showed that an average of 0.37 white flies of the first generation had matured and that of this generation an average of 0.15 per leaf showed infection by fungous diseases. These, with a very small average of less than 1 per leaf dying from unexplained causes, represented the entire first generation as shown by the examination of the leaves.

The July examination of No. 9 showed that an average of 0.2 white fly per leaf of the first generation had matured and that 0.46 per leaf was infected with fungous diseases. This low average of infection could not have had any appreciable effect on the normal increase of the insects, and it is obvious that in this grove the comparative freedom of the foliage from blackening was not due to the fungous diseases.

The very excellent condition as to white-fly infestation of grove No. 10 during the season of 1910 may be properly credited to the effective work of the fungous diseases after midsummer in 1909. The trees suffered so severely during 1909 from the excessive infestation that their unthrifty condition was noted at the time of the examination in July, 1910.

In No. 12 it was found, on July 1, that an average of 0.2 per leaf of the first generation had matured, while 0.74 forms of this generation showed fungous infection. As shown by Table II, the reduction in the number of the insects in this grove in 1908 was due almost entirely to an excessive rate of mortality from unexplained causes, fungous diseases being comparatively insignificant. As regards the cause for the failure of the live insects found in December, 1909, to multiply normally, No. 12 must be classed with No. 9. In both these cases the explanation is probably similar to that in the case of No. 8.

When the data in Table IX are examined with due consideration of circumstances known to the authors, it appears that the fungous diseases in the eight groves were ineffective in 1908, but produced a condition in that year resulting in satisfactory freedom from the insects and blackening of the foliage in one grove in 1909 and with prospects for such a condition in at least one grove in 1910. As the investigation of fungous diseases was discontinued in 1909, there are no records as to the condition of the groves the following season. Since the actual cause of the temporary freedom from injurious attack is often obscure, as the foregoing records show, it is evident that less detailed observations, such as have formed the basis of the estimates of the authors of previous publications (including the senior author of the present publication), have favored the fungi rather than otherwise in crediting them with complete efficacy to the extent of one year in three.

During 1906, 1907, 1908, and 1909 a large number of records were accumulated in regard to the efficacy of fungous diseases during those years in about 25 citrus groves located in different sections of Florida, mostly in Lee, Manatee, Hillsboro, and Orange counties. In several instances authentic information has also been secured in regard to the efficacy of the fungi in previous years, as shown by the necessity for washing the fruit to remove sooty mold.

More than one-half of the total number of records are concerning hammock groves and the list includes the majority of groves in Florida where the fungous diseases have been exceptionally effective during the period under observation. In two instances groves have been noted or authentically reported as free from blackening for two successive years after being well freed from the insects by fungous diseases. These are offset, however, by several instances of groves showing no benefit whatever for three or more years after the fungous diseases have become well established. In the case of one grove in Manatee County, unfavorably located with respect to a general nursery with citrus, China trees, privets, and other food plants, it had been necessary for the owner to wash the fruit every year for a period of more than 10 years, except for less than one-half of one crop. Although the red and the brown fungi were always found present in abundance at each of the several examinations made by the authors, the trees were always found to be more or less blackened and in one instance noted as being as thoroughly blackened as any grove seen in Florida.

The hammock groves of Manatee and Lee counties have offered the best opportunities for observations of the fungous diseases under the most favorable conditions. During 1906 and 1909 the majority of the Manatee hammock groves were practically free from blackening by sooty mold, but the crop of 1907 in these same groves was as

thoroughly blackened as any to be found in the State and in 1908 was only slightly improved. In Lee County the hammock groves located near the Caloosahatchee and Orange Rivers have been much less uniform than hammock groves in Manatee County as regards the efficacy of the fungous parasites. It has been more frequent to find very effective work by the fungi in one section of a grove, while another section of the same grove has been heavily infested and thoroughly blackened. On the whole the average condition in these groves in Manatee and Lee counties has conformed entirely to the estimates given in previous publications; in effect, that the efficacy of the fungi amounts to about one-third of a complete remedy.

In the interior of the State, in high pine land groves, the natural efficacy of the fungous parasites appears to be somewhat less than in the hammock groves referred to. Prof. Gossard mentioned the presence of the red and the brown fungi at Orlando in his annual report for the year ending June, 1901.¹ According to an authentic report, the grove of Hon. J. M. Cheney (grove No. 3 of Table I, and No. 1 of Tables II and IX) at Orlando was one of the earliest in that section to become infected with the red and the brown fungi. This introduction was not later than 1901. In 1907 the grove was entirely free from sooty mold, as noted in the discussion of unexplained mortality. This was the first year that the fruit had not been generally blackened since the introduction of the fungi, and the fungous diseases in this case were not responsible. In 1908 and 1909 the trees and fruit were very black, while by the end of the latter season the insects had been reduced in an entirely satisfactory manner. While we have no record concerning the condition of the crop for 1910 in this grove, it may be said without hesitancy that if not clean it was due to the interference with the efficacy of the fungi by adult white flies migrating from other groves or from China and umbrella trees. Without doubt China and umbrella trees have seriously interfered with the natural efficacy of the fungous parasites in Orlando and other cities and towns in Florida, but at the most the natural efficacy of the fungous parasites at Orlando and at similar locations apparently will not equal the natural efficacy in the hammock groves of Manatee and Lee counties.

COMPARATIVE EFFICACY OF DIFFERENT SPECIES OF PARASITIC FUNGI.

In the preceding topics, under the general heading of natural efficacy, the brown, red, and yellow parasitic fungi have been discussed collectively. All other species so far reported as white-fly parasites are of negligible value, as shown elsewhere. The brown fungus has long been considered as more effective than the red fungus against the citrus white fly. This estimate is in accordance with our obser-

¹ Rept. Fla. Agr. Exp. Sta., p. 65, 1901.

vations. An examination of 100 leaves picked at random in 5 typical groves in Manatee County and 5 in Lee County in January, 1909, showed a ratio of 14 red-fungus pustules to 32 brown-fungus pustules in groves which had all been infected with both species for several years previous. In 9 of the 10 groves the total number of pustules of brown fungus counted exceeded the total number of red-fungus pustules. The single exception was a grove in which both species of fungous parasites were present in almost negligible amounts. In Orange County the brown fungus has also as a rule shown greater natural efficacy than the red wherever the two species have both been present in the same grove and both have become well established. For example, in grove No. 1 of Tables II and IX the average number of red and brown fungus pustules per leaf was found to be 9.9 and 14.5, respectively, in December, 1909, and 3.7 and 52.9 in December, 1910.

The natural efficacy of the yellow fungus against the cloudy-winged white fly is about the same, according to the authors' observations, as the natural efficacy of the red fungus against the citrus white fly. The fact that the red and brown fungi have shown very little adaptability to the cloudy-winged species has been mentioned elsewhere.

HAVE THE FUNGOUS PARASITES INCREASED IN NATURAL EFFICACY SINCE THEIR FIRST DISCOVERY?

The statement sometimes heard to the effect that the fungous diseases are more effective now than formerly is unquestionably without the slightest foundation, and it is unnecessary to devote any space to a discussion of the subject.

ARTIFICIAL MEANS OF SPREADING FUNGOUS DISEASES.

HISTORY OF WORK IN THIS LINE.

Dr. H. J. Webber, who first discovered the red *Aschersonia* and the brown white-fly fungus, was also the first to undertake experiments with artificial methods of spread.¹ The methods tested included mixing the spores of the *Aschersonia* with water and spraying the infested leaves with an atomizer, hanging branches with pustules of the *Aschersonia* and brown white-fly fungus above branches infested with the white fly in groves where the fungous parasites did not occur, and transplanting young trees with parasitized white flies. The first method is reported to have failed to give satisfactory results. The second method was tested several times, but results were obtained in only one instance in the case of the red *Aschersonia* and once in the case of the brown fungus. The season of the year when these tests were made is not stated. The transplanting of young trees seemed the most reliable method, and this was recommended in estab-

¹ Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., pp. 26 and 30, 1897.

lishing the red *Aschersonia* and the brown fungus in groves where these white-fly enemies did not occur.

Prof. H. A. Gossard¹ tested pinning fungus-infected leaves onto leaves infested by the white fly, as also spraying with spores of the fungus and fragments of its mycelium suspended in water. These and certain other methods of less practical interest Prof. Gossard states "have been tried by various experimenters, myself included, without marked success." He adds: "However, an infection is sometimes started by these methods." With the knowledge concerning the fungous parasites obtained up to the time of writing (1903) Prof. Gossard recommended the transplanting of young trees as the most reliable method of spreading the parasites.

At the beginning of the present investigations in July, 1906, spreading the white-fly fungi by pinning the infected leaves onto uninfected trees was the method commonly employed. This method was successfully used, together with the so-called tree-planting method, in introducing the red *Aschersonia* and the brown fungus into a grove in Orlando as long ago as 1898 or 1899.

Dr. Berger has recorded experiments in pinning leaves infected with red *Aschersonia* in June and July, 1906, and in spraying the spores in a water solution in July and August, 1906. Results of pinning leaves infected with brown fungus and of spraying water solutions of brown-fungus mycelium incidental to experiments with red *Aschersonia* have also been noted by the same author. Dr. Berger was the first experimenter to obtain results in spraying water mixtures of the spores, justifying the use of this method in preference to the tree-planting method or leaf-pinning method. He was also the first to recommend that the spraying method be used to spread red and yellow *Aschersonias* in groves already infected in order to aid artificially in their multiplication and in the increasing of their efficacy.

EXPERIMENTAL METHODS.

In connection with the present investigations extensive experimental work has been conducted to determine the best methods and most favorable conditions for introducing the fungous parasites into groves where they do not exist, as well as to determine to what extent practical benefit can be derived through artificial methods of spread and encouragement of the growth of these fungi in groves where they already are present and well distributed. During 1906, 1907, and 1908 a total of about 3,500 trees was included in the experimental work. In addition, fully as many trees sprayed with water mixture of spores by citrus growers as independent experiments have been carefully examined and extensive data concerning the results obtained.

¹ Bul. 67, Fla. Agr. Exp. Sta., pp. 624-625, 1903.

During 1909 about 2,000 trees were included in the experimental work conducted.

Various methods have been employed in experimental work in the artificial dissemination of the fungous diseases. The tree-planting method recommended by Dr. Webber and Prof. Gossard and the leaf-pinning method commonly employed previous to 1907 have both been tested as checks on other methods. Spraying water mixtures of spores of the red and yellow *Aschersonias*, which, as heretofore stated, was first successfully used and recommended by Dr. Berger, has been most extensively used, as this method has proved the most satisfactory for use on a large scale. Preliminary tests of using water mixtures of spores in September, 1906, by the senior author seemed to show that the spores were affected by pressure in passing through an atomizer or spraying nozzle.¹

Consequently, two other methods were used which, so far as known, had not been previously tested. These methods, with their various modifications, have been called the dipping and the brushing methods.

Aside from the tree-planting and leaf-pinning methods and the methods mentioned in connection with the dissemination of fungous infection by means of water mixtures of spores and mycelia, the authors have tested and in correspondence recommended for use the rubbing of the underside of infected leaves against the underside of the leaves of uninfected trees. This has been done both with single infected leaves and with twigs with several infected leaves attached. It has also been tested with dry and wet leaves. The rubbing method has been most extensively used in experiments in the dissemination of the brown fungus.

PINNING AND RUBBING INFECTED LEAVES.

The pinning of infected leaves in introducing the *Aschersonias*, being obviously an inferior method, has been used by the authors principally in the form of checks on other methods tested. Infection was not secured in more than 50 per cent of the experiments, and when secured was a more local infection than those following spraying. Better results followed when the upper surface of the fungous leaf was brought into contact with the underside of the leaf to which it was pinned, although good infections have followed when the fungus pustules have been placed against the leaf. In all instances where infection followed pinning, fungus developed either on the leaf to which the fungous leaf was pinned, or more often on leaves immediately below, and occasionally on leaves so located that they might have been brushed against the fungous leaf by winds. In view of the greater abundance of infections occurring immediately below the

¹ Later experience indicates that the unsatisfactory results obtained were due to lack of suitable weather conditions.

fungous leaf, the authors conclude that showers and abundance of larvæ and pupæ are conditions most favorable to successful pinning. Good infections have been secured at times when there were no adults on the leaves.

While there are cases on record where very good results in introducing fungus have followed the pinning method, this must be regarded as second in importance to the introduction of spores in water mixtures, especially when *Aschersonias* are concerned. On the other hand, infections with the brown fungus have been secured with more certainty by pinning than by spraying, although with no more certainty and in a less widespread manner than by the dipping of infested shoots into ground brown-fungus leaves and water as described elsewhere. Infections with brown fungus by pinning have been secured as late in season as November 6 (1908).

Infections secured by rubbing fungus-infected leaves, as described under experimental methods, have proved of more value in connection with the brown fungus. Although success has attended the introduction of the *Aschersonias* by this method, they are too easily introduced by water mixtures to warrant attempts at introducing them by rubbing. Under favorable weather conditions the rubbing method is many times superior to the pinning. At most, rubbing, even for brown fungus, is a very uncertain method, as only a very small percentage of leaves rubbed become infected. In a hammock grove at St. Augustine, Fla., in August, 1907, the senior author rubbed about 1,200 leaves on four trees, the leaves averaging about 75 *citri* larvæ and pupæ. Infection resulted only on about two twigs. Later in the season slightly better results have been obtained. When only a few brown-fungus-infected leaves are obtainable, they can best be used for rubbing and then pinning. Frequently leaves that appear to have been rendered worthless by rubbing have caused infections when pinned. Fungous leaves should be kept wet or moist during rubbing by frequently dipping in water. Good infections with brown fungus have been secured as early as June 5, 1907, and as late as October 31, 1908, although September and October have proved more favorable months than the three preceding. While Prof. Fawcett reports¹ success in obtaining infections by means of the brownish sporodochia, which are found dusted over the surfaces of the infected leaves, several similar tests by the authors made at various times since June, 1907, have all been without results.

WATER MIXTURES OF SPORES AND MYCELIA.

Preparation of mixture.—Whichever of the three most promising methods of introducing the fungi in water mixtures is to be followed, viz, spraying, dipping, or brushing, the initial steps in the preparation of the mixture, with few exceptions, are the same. The "fungous

¹ Science, vol. 31, no. 806, p. 913, 1910.

leaves," as leaves¹ bearing fly larvæ and pupæ infected with fungi are popularly called, are placed in water, allowed to soak a varying length of time, and then shaken or stirred vigorously for from three to five minutes in order that the spores may be washed from the pustules, or, if brown fungus is used, that in addition small pieces of the mycelia may be separated from the leaves. After the leaves have been thoroughly agitated by shaking or stirring, the mixture is carefully strained, if it is to be applied as a spray, like ordinary insecticides; or, if the dipping or brushing methods are to be followed, merely poured into the final receptacle, together with the leaves and fungus. This stock mixture is then diluted to the desired strength.

In securing infections with the brown fungus, infections have been secured by using ground fungous leaves. In preparing water mixtures of the mycelia in this way, the leaves are first passed through an ordinary meat grinder or similar instrument. During this process the leaves are thoroughly ground into small particles. The ground leaves may be shaken in a jar, then poured into a bucket, thoroughly stirred, and the resulting mixture used for dipping the ends of white-fly infected branches.

As the spores are very readily gotten into solution, no special apparatus is necessary. The authors have found an ordinary 2-quart fruit jar very convenient when no more than 3 or 4 gallons of solution are desired at any one time. The fungous leaves are placed in the jar previously half filled with water, the top screwed on, and the contents shaken the desired length of time. In making larger amounts of spray, an ordinary washtub is a convenient retainer; the leaves being thrown into the tub half filled with water and vigorously stirred with a stick or board. The solution is then strained through a wine strainer into the spray pump and is ready for application.

Means and methods of applying water mixtures of spores.—For those who have only a few trees into which they wish to introduce fungi and do not care to go to the expense of purchasing spray pumps, very satisfactory results will be obtained by the use of an ordinary wooden bucket half filled with spore solution into which the badly infested outer shoots of the tree are dipped. In using the brushing method an ordinary whisk broom, or even a bunch of leafy twigs, in addition to the bucket, is all that is necessary.

In spraying the spores into the trees, the authors have used ordinary knapsack sprayers, compressed-air sprayers, and barrel pumps. There is little choice between these sprayers from the standpoint of infection secured, and the sprayer used has depended largely upon the

¹ The danger of introducing by means of fungous leaves either the citrus or cloudy-winged white fly into sections or groves where both do not occur is very great. When a grove is infested by only one species, the danger of introducing the other by this means may be obviated by scraping the red and yellow *Aschersonia* pustules from the leaves or by crushing the leaves, particularly those infected with brown fungus, in a meat chopper.

preference of the grower and the amount of work to be done. The compressed-air sprayer has a capacity of 3 gallons, and besides having the advantage of being somewhat lighter has a valve by the use of which the spray can be instantly cut off by the operator, thus preventing loss of solution in passing from tree to tree. It has the disadvantage of requiring frequent pumping up, and having been in use for some time, this feature is apt to become a serious drawback. Knapsack sprayers and barrel pumps, new or thoroughly cleaned, were found less likely to cause delays in work.

The method of procedure in the grove has differed but little from that by which insecticides are applied, and is very simple. In using knapsack or compressed-air sprayers it has been found very convenient to have as many jars on hand as there are sprayers. After the fungous leaves have been shaken the solution is strained directly into the tank and then diluted to its capacity. The jars are then refilled with another supply of leaves and water and allowed to stand until the contents of the first tank have been sprayed out. After the first shaking, the leaves have been used to advantage a second time when the supply was limited, but when an abundance of fungous leaves was available it was found to be a better policy either to throw them away or add fresh leaves for reasons mentioned elsewhere. Where three or four sprayers were in use it was found to be of advantage to have an additional man to keep the water supply replenished, shake the fungus, and change the base of supplies, so as to save time in traveling back and forth.

When using a barrel pump, in view of the larger amounts of water necessary, it is more essential that the tub or other retainer be placed near a larger supply of water. After the spore solution had been prepared and strained into the barrel, the latter was filled and the solution sprayed. Meanwhile the tub was again partially filled and more leaves added to soak and be stirred in readiness for the next barrellful of solution.

In spraying with knapsack or compressed-air sprayers, or in brushing, best results were obtained by directing the spray onto the underside of the leaves of the outer, more heavily infested, shoots. Experiments have shown that better infections were obtained on the outer portions of the tree than on water shoots. With a barrel pump two leads of hose were used to advantage, the halves of two rows being sprayed as the wagon passed between the rows.

The dipping method was first used as a check on experiments with other methods, but as it has been found to have a practical usefulness under some conditions, it has been frequently recommended by the authors to citrus growers. The water mixture is prepared as already described. A clean bucket half full of the unstrained mixture is held with one hand and arm in such a manner that with the other

hand the ends of the branches of the white-fly-infested tree can be momentarily immersed. This method is especially desirable where there are only a few trees to infect with the fungus and no satisfactory spray pump is available; also when only a few fungus-infected leaves can be obtained—as is frequently the case—and the greatest economy in the use of the water mixture is needed. The branches and twigs most heavily infested with the insects should be selected. For the dissemination of the brown white-fly fungus this is probably as satisfactory for general use as any method now known, the mixture being prepared as hereafter described in a slightly different manner than in the case of the mixtures of *Aschersonia* spores.

The brushing method consists in dipping a whisk broom or a substitute in the unstrained water mixture and brushing the underside of the leaves of the trees to be infected as far as within reach and throwing the water by means of the brush against the underside of the leaves higher up in the trees. This method, like the dipping method, can sometimes be employed with advantage in the case of the red and yellow *Aschersonias* and is especially useful in the case of the brown fungus, where unstrained solutions are naturally more desirable.

MISCELLANEOUS EXPERIMENTS AND OBSERVATIONS.

As infection was almost invariably secured in favorable seasons with fresh fungus material when spores of either the red or yellow *Aschersonia* were introduced by spraying, dipping, or brushing, it became apparent that the problem to be solved in connection with the introduction of fungi was not that of how to secure an infection, but by what means the ordinary infection secured by haphazard work could be increased by careful attention to the details. The results, however, of over 500 experiments conducted by the authors, together with those of growers, have been so variable that, at the end of three years of experimentation, little has been added to our practical knowledge of how to insure satisfactory infections. These same statements apply to the brown fungus, although the securing of an infection with this fungus is at no time so certain as with the red or yellow *Aschersonias*.

Results of straining water mixtures of spores through cloth strainers.—In straining the solution before spraying, the authors have found a fine-wire strainer (about one-sixteenth-inch mesh) of most value. Under no circumstances should cotton cloths be used as strainers, for microscopic examination of strained and unstrained solutions shows that a large percentage of spores fails to pass through the cloth. Mr. E. L. Worsham found, as a result of 36 microscopic examinations of solutions strained and unstrained, that about one-third of the spores were lost when ordinary cheesecloth was used as a strainer.

Examinations by the junior author have shown that even a larger percentage of spores may be lost. It was found that a closely woven cheesecloth removed as high as 73.8 per cent to 92.8 per cent of the spores, while an ordinary coarse towel removed 41 per cent. In obtaining these results one-tenth cubic centimeter of solution of red *Aschersonia* spores and water was placed on a glass slide marked off into one-tenth millimeter squares, and the counts made beneath a compound microscope. While the results thus obtained were subject to much variation, they all demonstrate that cloths should be avoided as strainers. Similar examinations of solutions strained through fine-wire strainers showed that practically no spores are lost.

Amount of fungus to use.—Experiments to determine the most economical amounts of fungus to use per gallon of water have given such varying results that no dependence can be placed upon the data obtained. Even under identical and apparently most favorable weather conditions, in experiments conducted at the same time and on trees equally well infested and favorably located, frequently as good infections have resulted from the use of 200 pustules as from 4,000 pustules per gallon of water. This is equally true of results obtained when only a few or a larger number of trees were included in the experiments. Within reasonable limits, the amount of pustules to use, therefore, depends entirely upon the amount of fungus obtainable. In all of the experiments herein reported, unless otherwise stated, 200 or more pustules have been used to each gallon of water.

Advantages of soaking fungous pustules before shaking or stirring.—A series of experiments in which the fungus was allowed to soak for different periods between 5 minutes and 48 hours showed that it is immaterial how long the fungous pustules remain in the water before shaking, provided, of course, that they are not left soaking an unreasonable length of time. Experiments have furnished no data to even warrant any soaking of the fungous leaves if they are comparatively fresh, except such as takes place during shaking or stirring. As good infections have been secured repeatedly when pustules were shaken as soon as placed in the water as when soaked several hours.

Number of times fungous pustules can be used to advantage.—Several experiments have been conducted to determine this point with definite results. Twelve hundred and 1,800 pustules of red *Aschersonia* in different experiments were shaken with a quart of water in a 2-quart glass jar for a period of five minutes. After pouring off the water used in the first shaking, fresh water was added and shaken as before, repeating up to four times. The quart of water used in each successive shaking was diluted to make 4 gallons of spray and applied to a given number of trees. In every test the third and fourth shakings

gave only the slightest trace of an infection or none at all, while the second shaking in four different experiments gave 20, 70, 4, and less than 1 per cent as much infection as the first shaking. The second shaking is, therefore, very unreliable as compared with the first. These field experiments have been supplemented by a microscopic examination of spore solutions.

Two hundred red *Aschersonia* pustules freshly picked in January were shaken five minutes in 1 quart of water, the solution poured into a clean dish, and the same pustules shaken again in a similar way three times. The solutions of the successive shakings were likewise poured into separate dishes. Each solution, in turn, was thoroughly stirred and the number of spores present in one-tenth cubic centimeter of solution (a very small drop) were counted by means of a slide marked into one-tenth square millimeters. The count gave the approximate numbers of spores in the successive solutions to be 9,188, 2,100, 274, and 19, respectively; or 79.3, 18.1, 2.4, and 0.2 per cent, respectively.

Effect of copper sprayers on vitality of spores.—It is a well-established fact that fungi are susceptible to the effects of solutions containing very small quantities of copper. Consequently, in purchasing spray pumps or retainers of any kind for work with white-fly fungi, it has been considered advisable on general principles to avoid copper and brass parts as far as possible. Numerous experiments have conclusively shown that equally good infections can be secured whether a copper or a galvanized-iron knapsack sprayer is used, provided the spore solution is not permitted to remain in the tank longer than is necessary to spray it into the trees. Throughout the summer of 1908 the authors used a copper and a galvanized tank in numerous duplicate experiments on different occasions, including nearly a thousand trees, and in all these no difference in infection secured could be detected. As good infections were secured when the copper tank was used as when the spore mixture was applied by means of a barrel pump, and as good as resulted in check experiments using the dipping and brushing methods where the spore solution was carried in a wooden bucket. Unsprayed trees developed no fungus except where the natural spread was rapid.

Effect of nutrients added to water mixtures of spores.—Experiments to determine what benefits, if any, accrue from the addition of nutrients to the ordinary water solutions of spores were begun in 1906, and were continued throughout 1907 and 1908. Agar, glucose-agar, glucose, and gelatin were used in varying amounts, and the solution allowed to stand varying lengths of time before application. As Prof. Fawcett has found a 5.10 per cent glucose-agar solution the best medium for the germination of the spores of the red *Aschersonia*, and that germination usually takes place in a little over 24 hours, field

experiments were conducted with the view to showing the effect of applying spores brought nearly to the point of germination in this medium. In this and other series of experiments the solutions were applied under favorable weather conditions, but no difference could be observed between the infection secured with nutrient solution and ordinary solutions used as checks. In some instances better infections were secured where no nutrient was added. Similar experiments with glucose as the nutrient have been reported by Dr. E. W. Berger¹ who also obtained negative results.

Effect of sulphur waters on spores.—Experiments to determine what effect sulphur water has upon securing infections with water solutions of spores have been conducted only in the grove. Artesian water from Manatee County was used. An equal number of red *Aschersonia* pustules (400) were soaked in sulphur water and in lake water for one-half hour, shaken thoroughly, and the solutions used for dipping on June 25, 1909. By July 10, on the six shoots dipped in sulphur-water solution, representing an aggregate of 54 leaves, 180 pustules had developed, while on the four shoots dipped in lake-water solution with a total of 28 leaves, 89 pustules developed. For each solution 3.3 and 3.2 pustules per leaf, respectively, were obtained. Check shoots developed no fungus. The results obtained gave no evidence of any injurious effect of the sulphur water on the spores of the fungus.

LENGTH OF VITALITY OF SPORES.

Field tests only have been made by the authors in determining the length of vitality of spores of white-fly fungi. No definite infections resulted from the use of fungi, either the *Aschersonias* or the brown fungus, collected from September to December, 1907, and applied in various ways during the following summer months. Infections were secured with fungus dropped by the cold in January, 1906, during the following June, although far better infections at the same time followed the use from freshly picked fungus, as a check. In all, the authors have used in their experiments about a barrel of fungus-infected leaves, collected during the early winter months, without success. In several instances a very minute infection, one or two pustules, was detected, but under such conditions that it was more than probable that the infection came from other sources. Special attention has been given to these experiments in order to determine the value of picking fungus-infected leaves in the fall so that much of the fungus that falls from the leaves during the winter months might be saved for spring infections. The results above mentioned would indicate that such fungus pustules are valueless unless some more successful method be devised for preserving the fungus-infected

¹ Rept. Fla. Agr. Exp. Sta. for year ending June 30, 1908, p. 111.

leaves than the usual drying process followed by the authors. In summer and fall, fungus left remaining on leaves, as well as when scraped off and kept in bottles, has produced infections as long as two months after picking.

RELATION OF WEATHER CONDITIONS TO FUNGOUS INFECTIONS.

While it is an established fact that good infections of the red and yellow *Aschersonias* are occasionally secured as early as April and May, and as late as early October, experiments have shown that weather conditions during these months are too subject to variation for even reasonably reliable results. Unless due regard be given to existing conditions, more failures than successes follow introduction at this season. Considering the difficulty with which fungus can be secured so early in the season, the tendency toward unfavorable weather conditions, and the better infections secured later in the season in return for the same expenditure of time and money, the authors do not recommend the introduction of fungi before June or, at least, until the summer rains begin. All experiments have shown that it is useless to force nature; that fungi can not be successfully introduced unless the weather conditions are such that the fungi are spreading naturally in infected groves. At Orlando this did not occur till June in 1907 and 1908, but in 1909 occurred by the middle of May. While infections of red and yellow *Aschersonias* have been secured as late as early October during the past three years, it is recommended that introductions of these fungi be completed during the summer rainy season. Our records show that numerous attempts by various means to introduce the brown fungus earlier than the 1st of September have frequently been failures, while previous to that time the slight infections secured have spread very slowly.

During the rainy season itself, all experiments to determine just what combination of humidity and temperature would give the best infections have, as a whole, been thoroughly negative. No difference in resulting infections has been observed whether the spore solutions were applied on bright, sunny days or on cloudy, muggy days; on ordinary days, days with frequent showers, or directly after such showers; at various times in the day from 5 a. m. to 6 p. m., with the temperature high and the humidity low, or vice versa.

It would appear that applications have been made under every conceivable combination of weather conditions, and from the entire mass of experiments nothing can be learned aside from the fact that it apparently makes no practical difference at what time of the day or under what conditions of humidity, temperature, prevalence of showers, etc., the spores are applied, so long as typical Florida summer weather prevails.

RELATION BETWEEN ABUNDANCE OF WHITE FLIES AND RESULTS IN
SPREADING FUNGOUS INFECTIONS.

While theoretically introduction of fungi should begin as soon as the presence of the white fly is discovered in a grove, the authors have met with such poor success with all attempts at such introductions that they have recommended the waiting until the white fly becomes abundant enough to cause a very slight blackening of foliage. Attempted earlier introductions have proved practical failures. It is contrary to natural laws governing the relation between host and parasite to expect to keep the fungus abreast of the fly all the time, and all experiments and observations during the past three years have failed to bring out a single instance where the fungus has spread, artificially or naturally, in a newly infested grove soon enough or fast enough to prevent the blackening of foliage. One can reasonably hope for success in holding down the fly in slightly infested groves only by careful attention to the direct remedial measures.

SUSCEPTIBILITY OF DIFFERENT STAGES OF HOST INSECTS.

Experiments have shown that the presence of no one instar of either species of white fly is essential to successful infections, or that any one larval stage is more susceptible to fungous attack than another, or than the pupal stage. Considering the large number of larvæ that hatch and the high rate of mortality that greatly reduces the number of forms in each successive instar, it is only natural that such leaves sprayed with spore solutions when the larvæ are very young should develop a large percentage of pustules on young larvæ. It has been found equally true that a much larger percentage of pustules develops on advanced larvæ and pupæ when introductions are made when the fly is largely in these later stages. A count of 40 leaves of various ages, picked promiscuously and with the citrus white fly in all stages, gave the percentages of red and yellow *Aschersonia* pustules developed on the first, second, and third larval, and on the pupal stage as 33, 32.1, 22.2, and 12.7, respectively. Another count following introduction of the fungus in experimental work gave in percentages of the total number of pustules developed: Pupal stage 36.5 per cent, third larval stage 34.5 per cent, and first and second larval stages 29 per cent. Examination showed that the various stages of fly were present in about this proportion at the time of the application of the fungous spores.

COST OF INTRODUCING AND SPREADING PARASITIC FUNGI.

The very low cost of introducing fungi into white-fly infested groves has influenced many to resort to this method of control, hoping to get much for little. Men who have taken up the matter in a commercial way furnish the supply of fungus and spray trees with water

mixtures of spores for about 2 cents a tree. At this price there is, of course, a fair margin of profit. The authors, with knapsack sprayers, and with the assistance of laborers at \$1.50 per day, have been able to spray 3 trees for 1 cent. One grower, by using a barrel outfit, with the aid of a boy at the pump, sprayed 100 trees with 50 gallons of solution in one hour. If one has to purchase fungus-infected leaves the cost is correspondingly higher. The very low cost of spraying fungous solutions can not fairly be compared with that of spraying insecticides or of fumigation if one considers the results obtained. Certain expenditures for either of these last methods of control may be expected to produce definite results that can be figured in dollars and cents if the remedy is properly applied. The returns for money spent in spraying fungus are never assured; if there is no infection in the grove at the time of the first application, the spraying may result in a temporary fungous control within three years, or it may ultimately cost the grower, through failure of the fungi to spread properly, much of his foliage and bearing wood as a result of secondary scale attack, to say nothing of a sharp falling off in the bearing of his trees, and other losses incident to white-fly infestation.

DEGREE OF INFECTION OBTAINABLE.

In field experiments it is impossible to distinguish the extent of direct infections with certainty, since natural spread usually takes place before the entire direct infection manifests itself. Even under the most favorable climatic conditions for fungous spread, only a very small percentage of the immature white flies which are exposed to spores from freshly matured pustules of red and yellow *Aschersonias* becomes infected. Many field tests have been made on a small scale, in which one or more branches heavily infested with white-fly larvæ and pupæ have been dipped or drench-sprayed with concentrated mixtures of *Aschersonia* spores.¹ In no instance has the resulting infection amounted to more than 5 per cent of the number of insects alive at the time of the introduction, and the apparently direct infection has rarely exceeded 1 per cent. In ordinary spraying on a large scale the direct infection on the parts of the tree reached by the spray is usually but a very small part of 1 per cent.

The brown fungus has proved much more difficult of spread artificially, as regards the degree of infection which it is possible to obtain by the methods tested as described elsewhere. During September and October, the most favorable season for brown fungus, introduction and infection are rarely secured on more than 1 per cent of white-fly-infected leaves² which have been dipped in water mixtures of

¹ Tests with red *Aschersonia* for the citrus white fly and with the yellow *Aschersonia* for the cloudy-winged white fly are particularly referred to.

² Since the brown fungus generally destroys all of the white flies on a leaf upon which it becomes established, it appears to the authors that the number of leaves infected is a better standard than is the actual number of insects infested.

spores and mycelia. The best general infection by brown fungus which has come under the observation of the authors was one secured in a grove¹ of Mr. W. C. Temple at Winter Park, by Mr. Frank Sterling of Deland. The ordinary method of spraying spores was used. The spraying was done between October 2 and 16, 1908. Doubtless there was more or less secondary spreading in the fall, but there was no appreciable spread in 1909 before April 23, when the records were made. At that time brown fungus was found to be present on 7 per cent of the leaves, averaging 23 pustules per infected leaf or 16 pustules for the entire lot of 100 leaves examined.

As regards the extent of infection attainable by methods herein discussed, the authors consider the results far from satisfactory. The dipping of white-fly infested branches in water mixtures of spores of *Aschersonia* and ground-up leaves infected by brown fungus would appear to represent a maximum of favorable influences so far as practicable methods of introduction or spread are concerned, and the failure to secure more than a slight infection, comparatively speaking, under any conditions indicates the relative insignificance of human efforts as compared with natural methods of spread.

PRACTICABILITY OF INCREASING THE EFFICACY OF FUNGOUS PARASITES.

The efficacy of the fungous parasites may be said to be increased, in a broad sense, whenever they are introduced or even spread naturally into white-fly-infested citrus groves in which they previously did not exist. The subject to be considered here, however, relates to the ordinary meaning of the expression "increasing the efficacy" after the initial introduction has already been accomplished. Apparently there are only two opportunities for effort in this direction. The first consists in producing conditions more favorable for the development of the fungous parasites and the second consists in artificially spreading the infection.

IMPROVEMENT OF CONDITIONS FAVORING THE DEVELOPMENT OF FUNGOUS PARASITES.

A line of work which naturally suggests itself in connection with an investigation of this kind is the improvement of conditions favoring the development of fungous parasites. Preliminary work in spraying trees with clear water in the absence of regular rainfall gave no promise of benefit. Common observations made in hammock groves in Lee and Manatee counties are sufficient to prove the futility of

¹ No examination of this grove was made prior to Dec. 8, 1908, but since no brown fungus was found in several surrounding groves, since none was known to occur nearer than 5 miles, and since no previous attempt had been made to introduce it, it was presumed that this fungus was introduced by Mr. Sterling. On the other hand, yellow and red fungi sprayed at the same time were presumed not to have been successfully introduced or spread by this application, since on the opposite side of the road a grove in which no artificial introduction had been made was found to have an average of twice as many red-fungus pustules and six times as many yellow-fungus pustules per leaf.

attempting materially to increase the efficacy of fungous parasites by artificially increasing the humidity. Even were it possible to secure a high percentage of humidity on high pine land in the counties mentioned and in the interior of the peninsula comparing favorably with the humidity in the most humid hammock lands, the accomplishment would avail nothing of practical importance.¹ If the conditions in these very hammock lands of Lee and Manatee counties were improved so that the work of the fungous parasites were sufficient to keep the crop of fruit free of sooty mold one year in two instead of, as at present, one year in three, the injury from the white fly would still be sufficient to demand more satisfactory means of control than natural enemies afford. Notwithstanding the apparently self-evident impracticability of efforts in this line, the careful investigation of the subject would be of much interest and possibly of usefulness in connection with the investigation of other fungous parasites affecting insect pests. In a small investigation conducted within reasonable time limit, however, the elimination of unpromising lines is necessary.

INCREASING THE EFFICACY BY SPREADING THE INFECTIONS.

The most important subject in connection with the investigation of white-fly fungous parasites is that of increasing their efficacy by artificially spreading the infection. At the time of this writing the only published record of the results secured by an attempt to spread infections where the fungous parasites already exist, and properly classifiable as a result of this kind, has been made by Dr. Berger.²

The authors' field investigations of this subject consist of personally conducted or cooperative experimental work in six groves in addition to more general observations in a few other groves where work in this line was taken up commercially. Altogether more than 1,500 trees were included in the experimental blocks in these groves, not including the untreated trees left as checks.

(1) *Gettysburg Grove, near Orlando, Fla.* Estimated 94.8 per cent citrus white fly, 5.2 per cent cloudy-winged white fly.—To determine what effect one introduction of spores of the red *Aschersonia* might have on the abundance of fungus in a grove already slightly infected,

¹ Since the preparation of this report the investigation by Prof. H. S. Fawcett, of the Fla. Agric. Exp. Sta., of a new disease of citrus fruits, known as "stem and rot" (Fla. Exp. Sta. Bul. 107, 1911), has shown that humid conditions in orange groves which are considered an advantage in favoring the white fly parasitic fungi are a serious disadvantage in also favoring the destructive disease of the fruit.

² Rept. Fla. Agr. Exp. Sta. for fiscal year ending June 30, 1909, p. xli. "On Aug. 17, 1909, red fungus was reintroduced into six trees in the Hawthorn grove in order to compare, at a later date, the amount of fungus in these trees with those not treated again. On Mar. 2, 1909, these trees were estimated by Mr. Jos. E. Kilgore and the Entomologist to have 10 times as much fungus in them as six trees in either row next to them, showing clearly that fungus should be introduced frequently, if necessary to get the best results."

blocks of trees in this grove (fig. 1) were sprayed as indicated with a spore mixture made by using about 1,200 pustules of red *Aschersonia* to each 4 gallons of water.¹

On August 21, almost before the introduced fungous spores had had an opportunity to mature into pustules, 27.6 per cent of the 185 trees sprayed August 10 were visibly infected with red *Aschersonia*, and 18.6 per cent of the 354 trees sprayed on August 11, while 15.5 per cent of 252 check trees showed the presence of fungi. A fungous inventory of this grove made during the following December showed the general infection represented in figure 1. A study of the distribution and comparative abundance of the fungus as indicated shows that it had no relation to the trees sprayed and that the spread from the middle of August on was entirely independent of any practical influence of the introduced spores. In fact some of the very best infections were on trees that were not sprayed.

A count of leaves picked promiscuously from the trees on April 30, 1909, gave data included in Table X.²

TABLE X.—*Red Aschersonia*; averages per leaf on sprayed and unsprayed blocks.

Rows.	1-3 check.	4-11 sprayed.	12-14 check.	15-20 sprayed.	21-23 check.	24-27 sprayed.	28-30 sprayed.	31-33 check.	Check rows.	Sprayed rows.
Live pupæ.....	0.7	0.5	0.4	0.1	0.4	0.1	0.4	0.3	0.4	0.3
Pupa cases (adults emerged spring of 1909).....	17.1	24.8	12.7	21.9	16.0	9.2	2.5	3.1	12.2	14.6
Spring mortality among pupæ.....	3.7	1.3	2.6	2.2	2.0	3.3	1.3	1.4	2.4	2.0
Red <i>Aschersonia</i> infection.....	9.0	17.7	8.6	6.3	7.2	2.6	.9	1.0	6.4	6.9

In Table X the forms recorded, aside from fungous infections, represent the total number of white flies surviving the winter. The spring mortality referred to is mostly the same as that discussed under the head of climatic conditions. The predaceous thrips mentioned elsewhere was also concerned in this mortality to some extent. It is evident from the data presented that absolutely no tangible benefit resulted from the attempt to spread the infection. A grove immediately south of the experimental grove, similarly infested with red fungus but in which no attempt was made to spread the infection, developed even more fungus than did the sprayed trees. An examination of 100 leaves picked at random in this grove showed

¹ Spraying began in the afternoon of Aug. 10, 1908. About 2 inches of rain fell during the morning and the afternoon was cool; the temperature for afternoon and night ranged from 74 degrees to 71.5 degrees F., while the humidity ranged from 92 degrees to 82 degrees and up to 99 degrees, where it remained close to 100 until 7 a. m., Aug. 11, when it gradually dropped to 63 degrees by 1 p. m., then rose suddenly to 94 degrees by 4 p. m., remained between 94 and 95 degrees for about one hour, suddenly dropped to 90 degrees, and then rose to 99 degrees and remained at 100 during the night of Aug. 11. The temperature at 4 a. m., Aug. 11, was 71.5 degrees F., gradually rose to 89 degrees F. by 12 m., and remained there until 2.30 p. m., then suddenly dropped to 74 degrees F. by 3.30 p. m., and then slowly dropped until 71 degrees F. was reached at 4.30 p. m. On Aug. 12 temperature rose to 92 degrees F. by 2 p. m. Subsequent conditions were very favorable for the spread of fungus.

² One hundred leaves were picked from each block, or 800 in all. The leaf averages are proportionally lower than in the records in Table II, since leaves were taken from all growths at random.

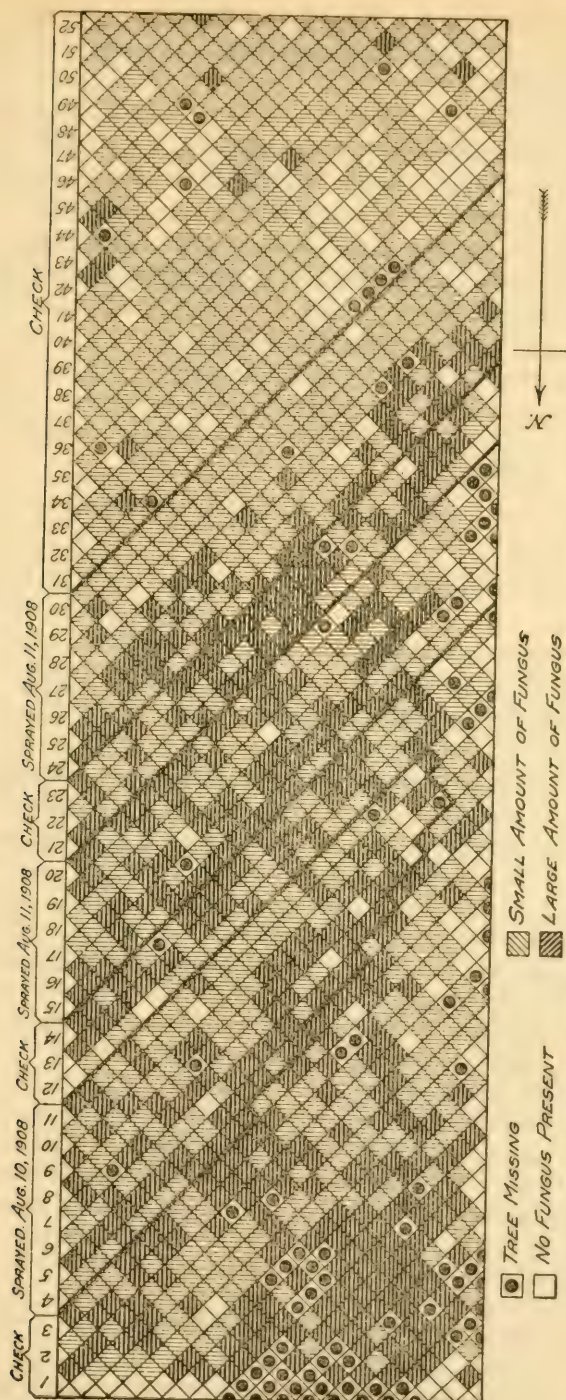


FIG. 1.—Diagram of Gettysburg Grove; experiment in spreading red-fungus infection in an attempt to increase its efficacy. (Original.)

an average of 29.8 red-fungus pustules per leaf, the degree of white-fly infestation agreeing quite closely with rows 4 to 11 (Table X) of the experimental grove.

(2) *Swindley grove, near Orlando, Fla.* More than 80 per cent citrus white fly; less than 20 per cent cloudy-winged white fly.—In this grove of 900 seedling oranges experiments were conducted during the summer of 1908 to determine what advantage might follow two introductions during the same season, and incidentally, one introduction on each of two successive years. About one-fourth of the trees were sprayed with no fresh red *Aschersonia*,¹ one-fourth with fresh red-fungus mixtures varying to strength (300 to 625 pustules per gallon) during July, and another fourth in a like manner during July and August. The remaining fourth, which had been sprayed during July, 1907, was again sprayed in August, 1908. The results are given in Table XI.

TABLE XI.—*Red Aschersonia: Results of experiments in spreading the infection.*

Block No.	Fungous introductions.	Leaves examined.	Pupa cases per leaf, average.	Red <i>Aschersonia</i> infection, average per leaf.
1	Unsprayed check.	120	9.8	0.01
2	Sprayed once, July, 1908.	120	6.2	6.1
3	Sprayed twice, July and August, 1908.	120	6.7	7.3
4	Sprayed twice, July, 1907, and August, 1908.	120	6.0	2.9

While the data presented show that more fungus developed on the trees sprayed twice in one season, the spread of the fungus on all trees during the season of 1909 was so rapid that it became impossible to tell which trees had been sprayed once, twice, or not at all. All developed an equally large amount of fungus which, supplementing unexplained mortality, so held the fly in check that the fruit in the grove was practically clean by the following fall. By the following spring much of the fungus had fallen off and there were more specimens of the fly in the grove during 1910 than the owner had noticed for many years, and the trees became thoroughly sooted.

(3) *Drennen estate grove, near Orlando, Fla.* The citrus and cloudy-winged white flies present, the latter comprising 0.8 per cent, according to an estimate made in June, 1909.—In this experiment a solid block of six rows of eight trees each was divided into two series, one comprising the even and one comprising the odd numbered trees of the six rows. Only a trace of red fungus (no yellow or brown) had been found in this grove and none had been discovered near the experimental block. After the first introduction, therefore, the experiment is properly one of increasing the efficacy by spreading the infection. An attempt was also made to introduce and spread the yellow and brown fungi by including their spores and mycelial

¹ This fourth was composed of trees either not sprayed or sprayed with dried pustules of the *Aschersonias* later determined to be valueless.

fragments with the red-fungus spores, but no results worth noting were secured.

Series A was sprayed 11 times between May 7 and October 19, using from 300 to 600 pustules per gallon of water.¹ The applications were made on the following dates: May 7, May 26, June 25, July 24, August 27, September 11, September 18, September 25, October 2, October 9, October 19.

Series B was sprayed only once, May 7.

Eight examinations, each based upon 300 leaves picked promiscuously from the trees of each series, gave the records shown in Table XII.

TABLE XII.—Average number of red-fungus pustules per leaf at successive examinations.

When examined (1909).	June 10.	June 30.	July 9.	July 24.	Aug. 14.	Aug. 27.	Sept. 11.	Oct. 26.
Series A, sprayed 11 times.....	0.22	0.5	1.2	3.5	5.1	10.1	20.1	21.5
Series B, sprayed once.....	.15	.3	.5	.8	2.4	6.0	8.8	9.5

A check lot of leaves picked promiscuously from unsprayed trees within three rows of the experimental block showed an average of two red-fungus pustules per leaf on October 26.

The rainfall and the comparative humidity² for each week during the six months covered by the sprayings are shown by the data in Table XIII, being based upon the mean of the maximum and minimum relative humidity records for each day by a Friez recording hygrograph located at the standard Weather Bureau shelter near the Orlando laboratory.

TABLE XIII.—Rainfall and relative humidity records, Orlando, Fla., May to October, 1909.

Week beginning—	Daily mean humidity.	Weekly rainfall.	Week beginning—	Daily mean humidity.	Weekly rainfall.
	<i>Per cent.</i>	<i>Inches.</i>		<i>Per cent.</i>	<i>Inches.</i>
May 3.....	76	.53	August 2.....	78	.9
10.....	82	.0	9.....	84	3.39
17.....	78	1.83	16.....	91	2.76
24.....	80	.0	23.....	86	.57
31.....	77	2.01	30.....	83	.73
Monthly mean.....	78.6		Monthly mean.....	84.5	
June 7.....	83	.05	September 6.....	81	.77
14.....	77	.0	13.....	82	.99
21.....	76	.59	20.....	86	1.65
28.....	77	8.23	27.....	87	.0
Monthly mean.....	78.2		Monthly mean.....	84.7	
July 5.....	91	1.03	October 5.....	81	.0
12.....	86	2.34	12.....	78	.0
19.....	81	.0	19.....	80	.28
26.....	80	1.59	26.....	79	.92
Monthly mean.....	84.5		Monthly mean.....	79.7	

¹ As in all experiments, unless otherwise stated, the freshest fungous pustules obtainable, according to the season of the year, were used.

² These humidity records are not comparable to U. S. Weather Bureau records, which in Florida are taken at 7 a. m. and 7 p. m.

It appears that the great humidity, after the introduction of September 11, was not a condition which would promote fungus development. The increases in the average number of fungus pustules per leaf are, as a rule, inconsistent, in series A and B, whether the data be examined from the standpoint of the attempts made to spread the infection or from that of climatic conditions. One exception is found in the rapid increase between the examination of August 14 and that of September 11 for both series. This most important increase of the year appears to be entirely uninfluenced by the attempts to spread the infection, since the fungus pustules in series B increased at practically the same rate as in series A. The pustules in series A increased about 200 per cent between July 9 and July 24, when practically uninfluenced by artificial spreading of infection, while the pustules in series B increased only about 60 per cent. Between July 24 and August 14 the attempt to assist natural means of spread was followed by a 46 per cent increase, while without any effort in this direction the natural spread in series B amounted to a 200 per cent increase in the number of fungus pustules.

Notwithstanding the foregoing inconsistencies the records show that after the initial introduction the fungus pustules multiplied about 10 times (964 per cent increase) in series A and about 6 times (623 per cent increase) in series B. It is not impossible that such a difference as this in the rate of multiplication might be found in two arbitrarily selected groups of trees treated identically as regards fungus introductions. We may, however, fairly give the fungus diseases the advantage of the presumption that the difference noted is due to the artificial spreading of the infection. The question then arises, Did this difference result in any practical benefit to the trees?

On June 30 an examination showed an average of 59 live larvæ and pupæ per leaf in the experimental block; on July 24, 21.5 per leaf; on August 27, 43.7 per leaf on old mature growth and about 350 larvæ per leaf on the newer summer growth, and on October 26 an average of 27.8 live per leaf. The last estimate was based on 10 typical leaves which averaged 27.5 red-fungus pustules per leaf and 10.4 pupa cases. While this examination was not extensive enough to compare with those the results of which are given in Table X, a summary showing more live insects in the leaves showing the most fungus infection is noteworthy.

Five leaves with greatest number of red-fungous pustules, averaging 47.6 per leaf, 36 live per leaf.

Five leaves with least number of fungus pustules, averaging 7.4 per leaf, 19.6 live per leaf.

It is probable that more adults migrated from the surrounding trees to the experimental block and from trees of series A to series

than vice versa, thus giving more live insects to those trees upon which the fungus spread best than they otherwise would have had. This, however, was an advantage so far as the increase in the average number of fungous pustules per leaf was concerned. On the other hand, the experimental block, which was heavily infested at the beginning of the season, began blackening by the 1st of June, and this heavy infestation would unquestionably have continued and a general blackening have resulted in spite of an increase in the number of fungous pustules to 21 or even 25 per leaf. From our data in this experiment and from our general knowledge of white-fly and fungous conditions, we conclude that no practical benefit to the orange trees resulted during 1909 from the repeated attempts to spread the infection of red fungus, and that from this standpoint the results would not have been affected if the trees of series A had been isolated. The only accomplishment of practical importance was in the introduction of the red fungus onto trees not previously infected.

(4) *Wills Grove, Sutherland, Fla. Grapefruit trees infested by cloudy-winged white fly only.*—In cooperative experimental work, in 1909, Mr. F. L. Wills, of Sutherland, Fla., sprayed 49 trees in the middle of a block of 378 trees, all heavily infested with the cloudy-winged white fly, and already slightly infected with yellow *Aschersonia*, with mixture of yellow *Aschersonia* on May 18, June 11, July 8, August 9, and after the 1st of September until October 18 one-half of the sprayed trees every two weeks, the rest once a month. By July 17 a count of 185 leaves, picked promiscuously, showed that 173 were infected, with an average of 41 pustules per leaf, or nearly twice as many pustules as were present on leaves picked from check trees. On August 18 Mr. Wills noted that the fungus was spreading very rapidly and making its appearance over 20 acres of orange and tangerine trees adjoining. At the time there was an average of 90.7 pustules per leaf on the sprayed trees as compared with 51.8 pustules on the check trees. By September 22 a count of 200 leaves from the sprayed and from the unsprayed check trees showed the average abundance of pustules per leaf to be 118.4 and 137.5, respectively; in other words, by the middle of September, the natural spread in the entire block had been so rapid that there was more fungus in the check than in the sprayed tree. By the middle of November no difference could be noted on a general examination of the grove, and both the owner and the authors concluded that had no spraying been done the natural spread would have accomplished the same results.

(5) *Fairbanks Grove, Island Grove, Fla.—Orange trees infected with citrus white fly only; cooperative experiments arranged with Rev. J. J. Glass.*—The trees were fairly heavily infested and there was a

trace of red fungus present in the experimental block of 26 orange trees located in the midst of a 10-acre grove. An examination of 100 leaves of old growth picked at random from the experimental block showed that an average of 12.6 had matured in the spring of 1909 or were still alive on the leaves as pupæ. The new spring growth was beginning to become blackened by May 21 and was generally moderately blackened by June 15. The experimental block was sprayed by the foreman, Mr. John Engle, on May 17, June 9, July 2, August 2, September 2, and September 11, using about 2,000 pustules of red fungus for the first and about 4,000 pustules of red fungus for each later spraying. One hundred and fifty leaves picked at random on June 15 had an average of 7 pustules of red fungus per leaf; on August 21, 140 leaves had an average of 8.8 pustules, and on September 15, 50 leaves had an average of 19.6 pustules. On August 2 Mr. Engle wrote to the effect that the fungus seemed to be working as well in other sections of the grove as in the experimental block. At the end of the season no difference could be detected so far as showing the slightest advantage from the repeated applications. An examination of two lots of leaves from surrounding unsprayed trees on September 15 and October 18 showed an average of 41.3 and 14.3 red-fungus pustules, respectively, on lots of 50 and 100 leaves. In regard to the record of October, a misunderstanding is involved which in the opinion of the junior author renders the record valueless, but even if it be accepted the data show that more fungus developed on the check trees immediately surrounding the experimental block than on the trees to which the spore mixture was applied.

(6) *Keep Grove, Boardman, Fla. Orange trees infested with citrus white fly only; cooperative experiment with Mr. B. B. Keep.*—The degree of infestation in this grove was practically the same as in the Fairbanks grove, but there was no fungous infection. A small block of 36 trees was sprayed. On May 3, a lot of 25 spring-growth leaves picked at random from the experimental block showed an average infestation of about 50 larvæ in the first three stages. Red-fungus spores were sprayed as in the preceding experiments within the first 10 days of May, June, July, August, and September. On October 25 an examination of 125 leaves from the sprayed block showed an average of 2.2 red-fungus pustules per leaf while from the surrounding unsprayed trees an average of 0.3 pustules was found on 134 leaves. On September 25 it was noted by Mr. Yothers that 72 out of 143 leaves examined from the experimental block had considerable sooty mold while the remainder were only slightly blackened.

THE DISADVANTAGES ACCRUING TO CITRUS TREES THROUGH THE USE OF PARASITIC FUNGI.

DIRECT INJURY TO FOLIAGE.

Dr. H. J. Webber gave the subject of direct injury to foliage some consideration in connection with the brown fungus and reported as follows:¹

Old leaves on which the larvæ have been dead for some time, and on which the fungus has been exposed for an extended period to the action of rain, etc., clearly show the slight damage to the leaf caused by this fungus. Leaves which were observed in March, 1896, to be badly infested with the fungus were found in December of the same year to show only the remains of the pustules, the hypothallus having been entirely washed away. That the fungus does some damage to the tree can not be denied, but this is clearly a secondary effect.

The secondary injury referred to by Dr. Webber has been noted by the authors. It may be considered as of slight importance. A more serious secondary injury frequently results from the prevalence of the yellow *Aschersonia*. Dr. Webber has noted² that sooty mold frequently surrounds and covers insects infested by the red *Aschersonia*. He states:

The honeydew collected around the infected insects furnishes nourishment for the sooty mold, which frequently springs up and makes a conspicuous growth. The growth of the sooty mold is more rapid than that of *Aschersonia* so that it sometimes happens that a rank growth of the sooty mold smothers both the insect and the *Aschersonia*.

The condition described is one which unquestionably interferes seriously with the respiratory functions of the infected leaf. The extent of the injury has never been estimated, so far as known to the writers. Fortunately this condition is not the usual one where the infection consists of the red *Aschersonia*. Such a condition is, however, quite typical when the yellow *Aschersonia* is abundant. Moreover, the yellow pustules themselves, being much larger than the red pustules developing on the citrus white fly, cover a correspondingly larger leaf surface. As has been indicated the secondary injury resulting from the yellow *Aschersonia* infection is of some importance and without doubt partly offsets the benefits resulting from the destruction of the white-fly larvæ and pupæ.

INDIRECT INJURY THROUGH THE DISUSE OF FUNGICIDES NEEDED TO COMBAT FUNGUS DISEASES.

In Florida the control of diseases³ of citrus by means of fungicides is seriously interfered with by the disadvantages and supposed disadvantages of the destruction of fungous parasites of destructive

¹ Bul. 13, Div. Veg. Phys. and Path., U. S. Dept. Agr., p. 29, 1897.

² *Ibid.*, p. 23.

³ The principal diseases preventable or partly controllable by means of applications of fungicides are known as melanose, die back, anthracnose, scab or verrucosis, withertip, and scaly bark. For the treatment of these diseases publications of the Bureau of Plant Industry of this department and of the Florida Agricultural Experiment Station should be consulted.

scale insects and white flies. In the case of fungous parasites which partially control the purple scale the disadvantage mentioned has been abundantly proved by the experience of many citrus growers. It is now recognized as necessary in most cases to follow up applications of a fungicide with applications of whale-oil soap or other insecticide suitable for checking the purple scale. Except in cases of extreme injury from plant diseases citrus growers of Florida are as a rule deterred from using fungicides on account of the indirect effect on the purple scale. A similar condition exists to a certain extent in white-fly-infested sections where the fungus parasites occur. That it is a mistake to allow hopes of possible benefit from fungous parasites of the white flies to interfere with the use of fungicides seems to the authors to be a clear deduction from the data herein presented regarding the efficacy of these diseases. Whenever the white flies are controlled by fumigation or by spraying the incidental control of the scale insects by the treatment primarily directed at the white flies will permit the more extended use of fungicides without fear of injurious secondary effects.

SUMMARY AND CONCLUSIONS.¹

From our present knowledge of the effects of climatological conditions upon the citrus white fly and cloudy-winged white fly, it is necessary to conclude that climatic conditions offer no hope of holding these insects in satisfactory control in any citrus-growing region where they may be introduced.

No true parasites of these species of white flies are known to exist in this country and their numerous native predatory enemies are usually of no material assistance in their control.

Two factors of natural control—overcrowding and unexplained mortality—have heretofore not been recognized or have been confused with the results of attempts at artificial control or with the effects of fungous diseases. The two factors named are in effect a reaction from excessive infestation.

Bacterial diseases of the white flies are at present unknown but it is not improbable that they are the leading cause of mortality so far unexplained.

¹ The conclusions of Profs. F. H. Billings and P. A. Glenn, from their recent studies of the well-known and highly overrated chinch-bug fungus, are of especial interest in connection with the investigations of white-fly fungous parasites. In Press Bulletin 40 of the University of Kansas they say:

"In fields where the natural presence of the fungus is plainly evident, its effect on the bugs can not be accelerated to any appreciable degree by the artificial introduction of spores.

"Moisture conditions have much to do with the appearance of chinch-bug disease in a field; artificial infection nothing.

"Advocating artificial infection or encouraging it by sending out diseased chinch bugs does not serve the best interests of the farmer, since his attention is thus diverted from other and truly efficient methods of combating the pests."

See also Bulletin 107, Bureau of Entomology, U. S. Department of Agriculture, "Results of the artificial use of the white-fungus disease in Kansas," by F. K. Billings and P. A. Glenn, 1911.

There is a wide margin in which natural enemies of the white flies may act, apparently with great activity, but with no practical benefit to the infested trees. The deceptive appearances thus explained have proved a serious hindrance to progress in white-fly control.

It is when several factors concerned in producing mortality among the insects are combined that the most satisfactory results are apparent.

Aside from unexplained mortality, fungous diseases are the most important agents of natural control. The brown fungus (*Aegerita webberi* Fawcett) and the red Aschersonia (*Aschersonia aleyrodis* Webber) are, in the order named, the most effective parasites of the citrus white fly. The yellow Aschersonia (*Aschersonia flavo-citrina* P. Henn.) is the most effective parasite of the cloudy-winged white fly. The cinnamon fungus (*Verticillium heterocladium* Penz.) and the Sporotrichum fungus (*Sporotrichum* sp.) are of comparatively little importance. The red-headed scale fungus (*Sphaerostilbe coccophila* Tul.) is rarely parasitic upon white flies, while the white-fringe fungus (*Microcera* sp.) is with little doubt normally saprophytic.

The fungous parasites thrive only under suitable weather conditions during a period of about three months each year; generally speaking the summer months in the case of the two Aschersonias and the fall months in the case of the brown fungus.

Their efficacy in destroying white flies under natural conditions is dependent upon the abundance of the insects; a period of excessive abundance always precedes effective temporary control.

Much damage has resulted in the past from ill-advised attempts to check the spread of white flies in newly-infested localities by means of fungous parasites.

The control of destructive diseases affecting citrus trees and fruit has been interfered with by fungous diseases and much preventable loss thereby incurred. This interference is due to the fear that the fungicides recommended for the diseases referred to would, if applied to the trees, check the white-fly fungus parasites with injurious results.

Under natural conditions, without artificial assistance in spreading, the fungi have ordinarily, in favored localities, controlled the white fly to the extent of about one-third of a complete remedy through a series of years.

The most successful method so far devised for introducing the red and yellow Aschersonias into groves where they do not occur is the spore-spraying method, first successfully employed and recommended by Dr. E. W. Berger. For the introduction of the brown fungus the brushing or dipping and the rubbing methods first used by the authors are as successful as any yet discovered, but are not

so reliable as the spore-spraying method for the *Aschersonias*. The infections secured by artificial means of introducing fungi, while successful in introducing the fungi, have thus far proved of little or no avail in increasing their efficacy after they have once become generally established in a grove. Experiments by the authors, and by citrus growers in cooperation with the authors, involving the treatment of thousands of trees with suitable "checks" or "controls" have shown that when fungus (red or yellow *Aschersonia*) even in small quantities is present in a grove there is no certainty that from three to six applications of fungous spores in water solution will result in an increased abundance of the infection on the treated blocks of trees by the end of the season. In some of the most important and carefully planned and executed experiments the fungus has increased more rapidly in sections of the groves which were not sprayed with spore solutions than in the experimental blocks. In no case has practical benefit been observed to result from efforts to increase the efficacy of the fungi in groves where they previously occurred. The above remarks apply especially to the *Aschersonias*. With the brown fungus, efforts to increase the efficacy have been equally disappointing from a practical standpoint.

As a result of the investigations reported herein and of observations and experience covering a period of four years the authors conclude that there are at present no elements of natural control herein dealt with which can be relied upon to give satisfactory results. Under present conditions it is unquestionably more profitable to depend upon artificial remedies.¹

There are, however, certain circumstances under which fungous parasites may be used to advantage. First may be mentioned the comparatively few citrus groves located in hammocks, with trees growing without regularity and with conditions such that fumigation or spraying with insecticides would be impracticable.² Second are those groves which are so situated that the failure to more than partially control the white flies will not interfere with the control of the insects in other groves and which for any reason it is impracticable to place on the most profitable basis of productiveness.

While it is recognized that everything possible should be done to secure and to test every procurable and possible enemy of both the citrus white fly and the cloudy-winged white fly, citrus growers in Florida should not await the outcome of this work with inactivity

¹ See Bul. 76 and Circular 111, Bur. Ent., U. S. Dept. Agr. Fumigation has already been dealt with in publications of the bureau. Spraying and other matters connected with artificial methods of control will be treated in later publications.

² Since the above was written the brown fungus has been so effective in controlling the white fly in certain very low-lying hammock groves in Lee County that it must be conceded this fungus has made artificial remedial measures unnecessary. Such groves, however, are an exception to the rule at the present time.

in the line of white-fly control. It should be borne in mind that even though an important and successful enemy should be discovered within the next two years, it would probably require several years before the practical results secured would justify the abandonment of artificial methods of control. On the other hand, in planning for the future the proportion of successes and failures of the past in obtaining successful natural enemies for various pests must be considered. Instances of such complete success as was obtained by the introduction of the Australian ladybird into California and later into Florida for the control of the cottony cushion scale are rare. Instances of only partial success or of entire failure are many. It is true that many failures have been due to the elementary condition of our knowledge of insect parasitology and that the failures of to-day and of the past may be overcome by advances in this line which may be made in the future. The field is almost unlimited in possibilities, and even the failure of the present foreign explorations should not lead to the abandonment of all hope of successful natural control.

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